The development of a framework to align the use of technologies in industries to the sustainable development goals

by
Joubert Spies

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Supervisor: Ms IH de Kock
Co-supervisor: Prof AC Brent

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Abstract

It is acknowledged that South Africa, and the rest of the world, faces sustainability challenges. Ideally, and in order to contribute towards sustainability, industries should continuously improve their activities through technological innovation and advancements. However, not all technological advancements contribute positively towards sustainability. Technology and technological innovation are seen by many as a major factor that can contribute towards sustainable development and the Sustainable Development Goals (SDGs). It is thus argued that sustainable development could be significantly influenced by technological innovation, and it is evident in literature that society and technology co-evolve and exert influence on one another. Therefore, one can infer that by aligning the objectives of industries with those of the technologies by means of SDGs, industries can positively influence the SDGs, and therefore also sustainable development, with the help of technology.

The present study investigates the role of technology (existing and emerging) in fostering sustainable development, and aims to highlight how sustainable development and SDGs are fostered within South Africa. The study further investigates how current frameworks guide industries towards choosing technologies within the context of sustainable development and to evaluate the applicability of such frameworks to the aim of aligning the objectives of industries with those of the technology by means of SDGs. Ultimately, the key objective of this study is to developed and effective framework to decision makers within industries that will ultimately provide guidance in choosing between technologies; the aim being to select technologies that contributes towards SDGs.

A systematic literature review is conducted to identify technologies that are used to support sustainable development within a South African context. Several technologies are identified, and emerging technologies, that holds potential to contribute towards sustainable developments, are identified and discussed.

There are various bodies in existence exist within South Africa that aim to ensure that positive progress is being made regarding planning and implementation of sustainable development, and given the focus of this research, the processes, focus areas and actions relating to how sustainable development is fostered in South Africa is identified as well as the challenges associated with achieving sustainability. Challenges include, for example, a lack of progress reporting on SDGs within South Africa. Further, the current status of South Africa is discussed in terms of SDGs and the various technologies could improve and/or contribute to the SDGs are highlighted.

Existing frameworks and their guidance towards choosing technologies are investigated, whereafter a short list of attributes are identified. These frameworks' applicability to the design requirement is determined and reveals that there is no existing framework that connects an industry and technology through the means of SDGs.

Guided by the eight phases of Jabareen's Conceptual Framework Analysis, the framework is iteratively developed. The validation process is completed through a series of interviews with Subject Matter Experts (SMEs) and the application of a case study, where after the incorporation of the validation findings are integrated into the refined framework.

The unique contribution that this study makes is the connection between industry and technologies through the means of SDGs. The framework guides the decision maker in choosing between technologies for implementation that foster similar SDGs to those of the industry. The validation results indicate a positive response; however, further studies on implementation, tracking the framework's performance through its implementation and the critical issues that arise from this are required.

Opsomming

Dit word erken dat Suid-Afrika en die res van die wêreld uitdagings vir volhoubaarheid ervaar. Ideaal gesproke, en om sodoende by te dra tot volhoubaarheid, moet nywerhede hul aktiwiteite voortdurend verbeter deur tegnologiese innovasie en vooruitgang. Nie alle tegnologiese vooruitgang dra egter positief by tot volhoubaarheid nie. Tegnologie en tegnologiese innovasie word deur baie gesien as 'n belangrike faktor wat kan bydra tot volhoubare ontwikkeling en die volhoubare ontwikkelingsdoelstellings. Daar word dus aangevoer dat volhoubare ontwikkeling aansienlik beïnvloed kan word deur tegnologiese innovasie, en dit blyk duidelik uit die literatuur dat die samelewing en tegnologie saam ontwikkel en invloed op mekaar uitoefen. Dit kan dus afgelei word dat die nywerhede die volhoubare ontwikkelingsdoelstellings, en dus ook volhoubare ontwikkeling, met behulp van tegnologie, positief kan beïnvloed deur die doelwitte van nywerhede met dié van die tegnologieë te bepaal deur middel van volhoubare ontwikkelingsdoelstellings.

Hierdie studie ondersoek die rol van tegnologie (bestaande en opkomende) in die bevordering van volhoubare ontwikkeling, en beoog om te beklemtoon hoe volhoubare ontwikkeling en volhoubare ontwikkelingsdoelstellings binne Suid-Afrika bevorder word. Die studie ondersoek verder hoe die huidige raamwerke industrieë lei om tegnologie te kies binne die konteks van volhoubare ontwikkeling en om die toepaslikheid van die soort raamwerke te evalueer ten einde die doelwitte van nywerhede met dié van die tegnologie deur middel van volhoubare ontwikkelingsdoelstellings te koördineer. Die hoofdoelstelling van hierdie studie is om 'n raamwerk op te stel wat effektief leiding gee aan besluitnemers binne nywerhede om n keuse te maak tussen tegnologieë; Die doel is om tegnologieë te kies wat bydra tot volhoubare ontwikkelingsdoelstellings.

'N Sistematiese literatuuroorsig word gedoen om tegnologieë wat gebruik word om volhoubare ontwikkeling, binne 'n Suid-Afrikaanse konteks, te identifiseer. Verskeie tegnologieë is geïdentifiseer, terwyl opkomende tegnologieë, wat potensiaal het om tot volhoubare ontwikkelings by te dra, geïdentifiseer en bespreek is.

Daar is verskeie liggame wat binne Suid-Afrika bestaan, wat daarop gemik is om te verseker dat positiewe vordering gemaak word met betrekking tot die beplanning en implementering van volhoubare ontwikkeling. Met betrekking tot die navorsing, die prosesse, fokusareas en aksies wat verband hou met hoe volhoubare ontwikkeling bevorder word binne Suid-Afrika, sowel as die identisifisering van die uitdagings wat geassosieer word met die behaal van volhoubaarheid. Uitdagings sluit byvoorbeeld 'n gebrek aan vorderingsverslagdoening oor volhoubare ontwikkelingsdoelstellings in Suid-Afrika in. Verder word die huidige status van Suid-Afrika in terme van volhoubare ontwikkelingsdoelstellings bespreek en hoe die verskillende tegnologieë kan bydra tot die volhoubare ontwikkelingsdoelstellings.

Bestaande raamwerke en hul leiding ten opsigte van die keuse van tegnologie is ondersoek waarna ’n kort lys van eienskappe geïdentifiseer is. Hierdie raamwerk se toepaslikheid op die ontwerpvereiste is vasgestel en gevind dat daar geen bestaande raamwerk bestaan wat ’n bedryf en tegnologie deur middel van volhoubare ontwikkelingsdoelstellings verbind nie.

Gelei deur die agt fases van Jabareen se Konseptuele Raamwerk Analise, word die raamwerk iteratief ontwikkel. Die bekragtigingsproses is voltooi deur middel van ’n reeks onderhoude met vakkundiges en die toepassing van ’n gevallestudie, waarna die inwerkingstelling van die validering bevindinge in die verfynde raamwerk geïntegreer is.

Die unieke bydrae wat hierdie studie bied, is die verband tussen industrie en tegnologie deur middel van volhoubare ontwikkelingsdoelstellings. Die raamwerk lei die besluitnemer na die keuse tussen tegnologie vir implementering wat soortgelyke volhoubare ontwikkelingsdoelstellings aan dié van die bedryf bevorder. Die validasie resultate het ’n positiewe reaksie aangedui; egter, verdere studie is nodig met implementering, die opsporing van die raamwerk se prestasie deur die implementering daarvan en die kritiese probleme wat hieruit ontstaan.

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Nomenclature

Acronyms

AU African Union

DEA Department of Environmental Affairs

ICT Information and Communication Technology

IoT Internet of Things

IRP Integrated Resource Plan

MLP Multi-Level Perspective

NCSD National Committee on Sustainable Development

NFSD National Framework for Sustainable Development

NGOs Non-Governmental Organizations

NSSD National Strategy on Sustainable Development

SBAS Satellite-Based Augmentations System

SD Sustainable Development

SDGs Sustainable Development Goals

SMEs Subject Matter Experts

SNM Strategic Niche Management

ST Socio-Technical

TA Technology Acceptance

TAM Technology Acceptance Model

TM Transition Management

UN United Nations

WCS World Conservation Strategy

Chapter 1

Introduction

1.1 Background of the study

The world faces unprecedented and fundamental sustainability challenges across a number of domains. These challenges are aggravated by path-dependencies and technological lock-ins, resulting in the established, incumbent Socio-Technical (ST) systems undergoing incremental changes, rather than the radical change that is necessary to effectively address sustainability challenges (Loorbach, 2010; Markard et al., 2012).

A ST system is defined by Geels (2004) as the "*linkages between elements necessary to fulfil societal functions*" (p. 900). ST systems theory has come a long way and around 60 years of development and application internationally by both researchers and practitioners has been performed (Baxter and Sommerville, 2011; Carayon, 2006; Cherns, 1976; Clegg, 2000; Davis et al., 2014; Eason, 2007, 2014; Mumford, 2006; Pasmore and King, 1978; Trist and Bamforth, 1951). The impact of these theories has had a significant impact on the social aspects of organisational design (the design of jobs and means of organising work). The re-design of ST systems in line with ST theory has helped improve work experience and generate more effective systems (Davis et al., 2014). ST systems theory incorporates the idea of design incompletion; the continuing need to review and revise our designs (Cherns, 1976).

Sustainable Development (SD) was defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (p. 9682) (Anadon et al., 2016; WCED, 1987) in 1987 through commissions and summits led by the United Nations. Since then, subsequent work has broadened the original framing to define development as sustainable when "inclusive well-being" does not decline with time (Anadon et al., 2016). From the perspective of SD, a number of ST systems (i.e. the energy sector, transportation system, etc.) are deemed unsustainable. It is argued that in order to transition from current (unsustainable) ST systems to sustainable ST systems, large-scale technological and social innovation diffusion is required (Bibri and Krogstie, 2017). When looking at solutions to sustainability challenges, it is evident that the solution is neither social, nor technically exclusive (Brundtland and Khalid, 1987).

Sustainability challenge engineers to ensure social, ecological and economic issues are incorporated into their work. Engineers are pushed towards considering cross-generational costs and benefits of their work, the rights of diverse social groups to resources, and the shaping of consumer needs to fit environmental limits (Bell et al., 2011). The mainstream discourse in SD argues for an eco-efficiency approach in which a technology push strategy boosts efficiency levels by a factor 10 and more in industrialised and developing countries (Paredis, 2011).

According to Le Blanc (2015), there is a lack of integration within ST systems in terms of strategies and policies, which remains one of the main pitfalls of previous approaches. The current lack of trade-off initiatives and interaction within ST systems results in muddled policies, unfavourable impact on SD policies, and finally a separation of outcomes and trends for SD (Le Blanc, 2015).

SD is controlled by technological innovation. Technology includes the full range of devices, methods, processes, and practices that can be used “to fulfil certain human purposes in a specifiable and reproducible way” (p. 9683) (Anadon et al., 2016; Brooks, 1980). Technology innovation evolves over time and changes according to changes in the market. Therefore, existence of feedback loops connecting activities in different innovation stages implies that overcoming barriers (Bergek et al., 2008) to innovation in any one stage often requires looking beyond that particular stage (Anadon et al., 2016).

It is commonly acknowledged that technology, in itself, has no power (Geels, 2002). Only when technology is effectively integrated with, and used and accepted by society, institutions, governing bodies and organisations, can technology fulfil its function (Brent, 2015). Additionally, organisations are profoundly affected by technological advancements and require a flexible customised change model to fit the social network of the industries and/or organisations into which technology is being introduced (Appelbaum, 1997).

Feenburg (1999) has stated that society and technology co-evolve and mutually influence each other. Johnson and Wetmore (2009) state that “if one wants to influence the direction of technology and society, one must first understand their relationship” (p. 95) and “understanding how values are entwined in ST systems is crucial to steering technology to a future we want” (p. 205).

For developing countries to foster economic development, organisations purchase new technologies and innovation to broaden their manufacturing base (Blohmke, 2014). Developing countries understand access to technology as key for economic development, thus they see the chance to gain stronger technology ownership and reduce their technological dependency on the developed countries through technological innovation. Developing countries have been expressed through the right to SD in the context of clean technology innovation (Blohmke, 2014).

Developing countries face barriers along the entire value chain, from financing of the technology manufacturing to operation and maintenance during the technology lifetime. The assessment of complexity can be understood as a framework for potential profit- and technology-sharing agreements between developing countries on the one hand, and high-income, technology exporting countries on the other hand (Blohmke, 2014). According to Paredis (2011), the transfer of technologies between social contexts - e.g. from industrialised countries to developing countries - is not a major problem and only inhibited by cost.

One of the main learning points for sustainable technology policies is that they should not focus on individual products and processes, but on ST systems and relations between different levels. In ST systems, traditional technology push strategies are not adequate, since they neglect co-evolutionary dynamics (Schot and Geels, 2008).

Making technological innovation work for SD requires making fundamental changes to the rules (Anadon et al., 2016). There has been tremendous research done in the field of ST systems and how technology changes it. With the constant change in technology and innovation, this field presents an opportunity for developing countries to establish how technology is implemented, managed and continuously improved. These changes to such systems can result in significant and cascading impacts to the assets that comprise the productivity base of a society (Blohmke, 2014).

It is clear that the current SDGs and the supporting policy framework does not completely reflect the multi-dimensional connections within the SDGs framework. Therefore, in practice, the implementation of technology within a ST system will be limited to certain SDGs, which could have reached multiple SDGs indirectly with guidance towards multi-dimensional connections (Le Blanc, 2015). According to Le Blanc (2015) there is an absence of important links that reflect the SDGs network as a whole and that have not yet reached the international political arena.

Understanding the dynamics and complexities surrounding the interactions between technology and ST systems with regard to SDGs is the focus of this research project.

1.2 Problem statement

The key to unlocking the potential capacity of using technology to contribute toward and/or improve SDGs is assisting the industries with a framework that provides the connection between a specific industry and technology. Currently, a lack of integration exists within the ST systems (Le Blanc, 2015) and through the re-designing of a ST system, effectiveness of the system may be improved (Davis et al., 2014). This is evident in the scientific literature, where it has been stated that society and technology co-evolve and influence each other (Feenburg, 1999).

There is a need to establish the connection between industries and technologies relevance towards the SDGs within the context of developing countries. The present study aims to understand the importance of context, specifically with regard to developing countries (and more specifically South Africa) when ST systems (and more specifically, industries) are considering the adoption of technology within respective industries.

Currently, there is a gap in the literature regarding the connection between industries and the various technologies. This remains a challenging landscape for a number of reasons, and more specifically their applicability to the South African context. The applicability of these technologies to assist industries in realising the potential of the technologies toward fostering sustainable futures remains unknown. In addition to the questions of context, when technology implementation is considered, within South Africa and new innovative technologies are being developed that holds potential to contribute towards sustainable futures. However, the existing frameworks, approaches and models to study ST systems and understand how technology implementation takes place have not been investigated. It is unknown how these frameworks can contribute to understanding the effect of these technologies on SDGs.

1.3 Research aim and objectives

The aim of this research study is contributing towards facilitating a process whereby industries can identify and select the most applicable/relevant/suitable technologies that will enable them to, in-turn, contribute towards the SDGs through the development of a framework to guide ST systems towards SDGs with use of technology in ST systems. For the purpose of this study, such ST systems, and thus the level of analysis, are industries. An effective approach to study, understand and explain the role of technology in industries, that holds potential to contribute towards the SDGs in South Africa and that will, ultimately contributing towards the greater promise of SD, as well as to the bodies of knowledge pertaining to SD and technology management.

The above stated aim are supported by the following objectives:

1. Investigate the role of technology in SD, as well as the factors that enabling and/or limit technology in contributing towards transitioning to sustainable systems. In addition, the role of technology in SD in South Africa is investigated. The focus will primarily be to:

    (a) Investigate what technologies are currently being employed in South Africa to support the aim of SD. And to develop a clear understanding of the extent of use of technology in South Africa in the process of fostering SD; and

    (b) Gain an understanding of available or emerging technologies that could potentially have a significant impact in South Africa in terms of SD.

2. Gain an understanding of how SD is fostered within South Africa and the current challenges faced in terms of moving towards sustainability. In addition, the study will investigate South Africa's current state on SDGs and areas of improvements through technological advancements.

3. Determine the applicability of the developed frameworks, approaches and models to the design requirements set out to guide decision makers when choosing a technology(ies) when implementing within an industry to improve and/or contribute towards SDGs.

   (a) Investigate how the existing frameworks, approaches and models guide decision makers when choosing between technologies for SD and more specifically towards SDGs.

   (b) Determining the applicability of the existing frameworks, approaches and models in relation with the design requirements to effectively support the process of implementing technology to contribute and/or improve SDGs.

4. Develop and validate an framework that will support the guidance towards choosing a technology(ies) for implementation within an industry to contribute and/or improve SDGs. In addition, perform a case study to exploit the practical use of the conceptual framework.

   (a) To develop a conceptual framework that can of support and guide decision makers, within industries, towards technology(ies) for implementation to contribute and/or improve SDGs.

   (b) Validate the conceptual framework by engaging with Subject Matter Experts (SMEs) in the field.

   (c) Perform a case study to explore and discuss the practical application of the use of the conceptual framework.

Ultimately, the success of this research project will lie in the ability of the developed framework to provide an effective way to provide guidance for decision makers within industries when choosing between various technologies to foster SDGs.

1.4 Research approach

This approach adopted in the current study exists of an amalgamation of theory development, framework building and validation. Chapter one articulates the problem landscape and acts as a framework for the study. The systematic review (refer to section 3) was conducted to gain and synthesise knowledge and gain a better understanding of concepts. The development of a framework was based on the guidance of Jabareen's Conceptual Framework Analysis, based on the Grounded Theory (Jabareen, 2009).

The developed framework was validated (refer to section 7.4) through a series of interviews conducted with Subject Matter Experts (SMEs). In order to provide a more realistic and useful framework, the necessary adaptations to the framework were made, including the feedback from the SMEs. A case study was performed to expose the framework to inspection and explore the practical application of the framework (Robert, 2014).

Chapter two outlines the research methodology and an overview of the theory used in this study, namely Grounded Theory and Conceptual Framework Analysis. The justification for the use of these theories is described, followed by the steps employed.

1.5 Limitations and assumptions of the study

This study includes some limitations and assumptions that should be noted. The systematic review methodology is advantageous as it reduces bias in the review process, but has limitations that should be noted and is further discussed in section 2.3.1.

Data collection was performed through the means of interviews with Subject Matter Experts (SMEs), where the SMEs was selected based upon their relevance towards the implementation/-management of technology for sustainability and research fields such as SD, technologies and knowledge of various industries. This is however a limitation to this study, as it could be of greater value to include various SMEs of all industries. There are various role players within each industry and acts as a limitation when identifying SMEs. The chosen SMEs is acceptable for this study as the SMEs have knowledge and expertise in a vast number of fields.

The framework, developed in this thesis, is limited to the three entities illustrated in Figure 7.1, namely technology, industry and SDGs. The framework does not include any other factors that does and/or may have an affect on the decision-making process. These limitations is also further address in section 9.3, where in section 9.4 future studies is identified to address these limitations.

1.6 Content of document

Table 1.1 summarises the outline of this thesis which flows in logical order based on the research approach outlined in section 1.4. The chapters in this thesis are structured as follows:

Table 1.1: Thesis outline

Chapter 1 - Introduction
Chapter 1 provides the background of the study and provides the problem statement, followed by the research aim, objectives and limitations of the study.
Chapter 2 - Methodology
This chapter presents and discusses the research methodology, including a description of the Grounded Theory methodology and Conceptual Framework Analysis applied to this research.
Chapter 3 - The role of technology in South Africa
This chapter presents a systematic review that was performed in order to identify the technology used in the socio-technical system within South Africa and further explains how the technology is used.
Chapter 4 - The unused, new and emerging technologies to foster sustainable Socio-Technical systems
Chapter 4 provides information regarding the available technologies that foster sustainable development and how these can change the South African environment in terms of sustainable development.
Chapter 5 - Sustainable Development, Sustainable Development Goals and identifying South Africa's SDG areas of improvement
This chapter discusses how sustainable developments are fostered in South Africa and identifies current challenges and focus areas. This chapter further provides information regarding the current state of South Africa's performance on the SDG's set out and discusses which areas can be improved through technological advancements, and how these can change the current state.
Chapter 6 - Existing frameworks, approaches and models
Chapter 6 presents and discusses the existing frameworks, approaches and models in the field of technology transitions and technology adoption. This chapter includes the design requirements of the developed conceptual framework and discusses the shortfalls of the current existing frameworks, approaches and models.
Chapter 7 - Industry and technology alignment with SDGs framework
In this chapter an overview of the theory is discussed where the relationship between the SDGs, industries and technology is explained. The chapter further developed a framework and describes the refined framework. Chapter 7 further explain how the refined framework can be used within practise. The last section of this chapter includes the first phase of the validation process. This chapter describes the validation process, discusses the validation results and provides solutions to areas that have been identified.

Table 1.1 continued from previous page

Chapter 8 - A case study of industry and technology alignment with SDGs within the South African energy sector
Chapter 8 presents and discusses how the framework can be applied to the energy sector. This chapter presents a case study of the framework on the energy sector within South Africa.
Chapter 9 - Conclusions and recommendation
The final chapter concludes the study with a compact summary of the research conducted, the conclusions of the study and recommendations for future work is discussed.

1.7 Chapter 1: Conclusion

To summarise, Chapter 1 provides an introduction to this study by first discussing the background of the study. The research aim and objectives defined to address this problem are listed and the research approach identified. The identification of this study's limitations is discussed, thereafter, the chapter concludes with a brief outline of the thesis. The following chapter discusses the research methodology used to achieve the objectives set out in this chapter.

Chapter 2

Methodology

Chapter 2 provides an overview of the methodology and theory used in this study, namely the Grounded Theory and Conceptual Framework Analysis. The benefits and features of Conceptual Framework Analysis is explained, hereafter the framework of steps performed in order to achieve the objectives is discussed.

2.1 The Grounded Theory Methodology

Grounded Theory has been defined as a theory that is derived from data, systematically gathered and analysed through the research process (Corbin and Strauss, 1990). Grounded Theory has specific tools that will contribute to the developing of a framework in the thesis. However, grounded theory still has limitations and has been criticised to some extent (Bryman and Bell, 2014). Grounded Theory utilises qualitative data or combines qualitative and quantitative data (Strauss and Corbin, 1994). According to Charmaz (2008), the main principles of the Grounded Theory include: minimising preconceived ideas about the research problem and data, using simultaneous data collection and analysis to inform each other, remaining open to varied explanations and/ or understandings of the data, and focusing data analysis to construct middle-range theories. Conceptual Framework Analysis, which is described below, offers a strategy to build a framework analysis based on Grounded Theory (Jabareen, 2009).

2.2 Conceptual Framework Analysis

According to Jabareen (2009), the use of a conceptual framework and theoretical framework are vague and imprecise however, he defines a conceptual framework as “a network, or ’a plane,’ of interlinked concepts that together provide a comprehensive understanding of a phenomenon or phenomena”. Grounded theory is adequate for conceptual framework building due its primary characteristics and thus, the Conceptual Framework Analysis, as he refers to, aims to generate, identify, and trace a phenomenon's major concepts, which together constitute its theoretical framework (Jabareen, 2009). The texts selected for Conceptual Framework Analysis should effectively represent the relevant social, cultural, political, and environmental phenomenon or social behaviour, and the multidisciplinary literature that focuses on the phenomenon under study.

2.2.1 Features of conceptual frameworks

The main features of conceptual frameworks are as follows (Jabareen, 2009):

i. A conceptual framework is a construction of concepts, where each concept plays an integral role (Miles and Huberman, 1994);
ii. A conceptual framework provides an interpretative approach to social reality;
iii. Conceptual frameworks provide understanding; and
iv. Conceptual frameworks are indeterminist in nature and therefore do not enable us to predict an outcome. (Levering, 2002).

2.2.2 Advantages of a conceptual framework

The main advantages of conceptual frameworks are as follows (Jabareen, 2009):

i. *Flexibility* - Conceptual frameworks are based on flexible conceptual terms rather than rigid theoretical variables and causal relations;
ii. *Capacity for modification* - Conceptual frameworks can be re-conceptualised and modified accordingly. This is consistent with the basic premise that social phenomena are evolutionary and not static; and
iii. *Understanding* - Conceptual frameworks aim to help us understand phenomena rather than predict them.

2.2.3 Phases of a Conceptual Framework Analysis

The proposed methodology is composed of eight phases (Jabareen, 2009), which are summarised below and depicted in Figure 2.1.

The first phase of the Conceptual Framework Analysis is the **mapping of selected data sources**. This phase include identifying the need to review literature, the identifying the gap and data sources. This information is subsequently used to identify the search terms and execute an extensive review of the literature.

Phase two consists of **extensive reading and categorising of the selected data**, this includes extensive reading of identified data sources to gain better understanding and categorising data.

Phase three **identifies and names the concepts**. The information is then further developed through refined reading and identifying of core processes.

Phase four is conducted by **deconstructing** each concept according to its attributes, characteristics, assumptions and limitations. This phase concludes with the **categorising of the concepts** to their distinct perspectives. The next phase, phase five, is then completed by **integrating the concepts** through grouping of similar concepts to form new concepts based on similarities.

Phase six revolves around the development of the conceptual framework, which is done through an iterative process building on integrated concepts. Phase six includes **synthesis, re-synthesis, and making sense of the findings**.

Validation of the conceptual framework is executed in phase seven and is an integral part of quality assurance of the framework. This phase includes questions around the proposed framework, conducting fieldwork and thorough feedback, which all determine whether the proposed framework and its concepts make sense.

Phase eight, **rethinking the conceptual framework**, consists of making the necessary changes according to the outcomes of phase seven. This phase may also revise the proposed framework according to new insights, comments and literature.

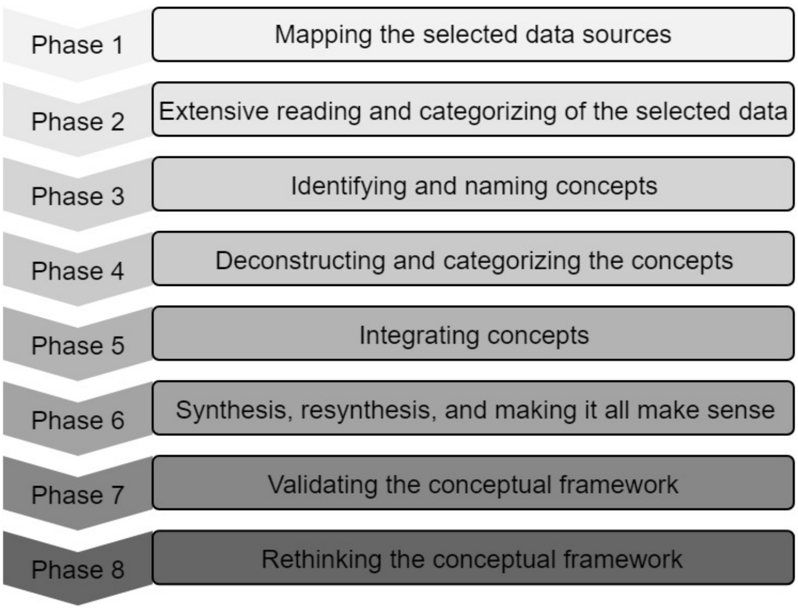

Figure 2.1: Conceptual Framework Analysis phases.

2.3 Research design

A overview of research design is represented in Figure 2.2 and consists of 3 parts. This section explains how the phases depicted in Figure 2.1 were utilised to complete the present study. The first part comprises phases one, two and three of the Conceptual Framework Analysis methodology. Phases four, five, six and the first section of phase 7 of the Conceptual Framework Analysis methodology are explained in part two. The last part, part three, concludes the study and includes the second section of phase seven and phase eight.

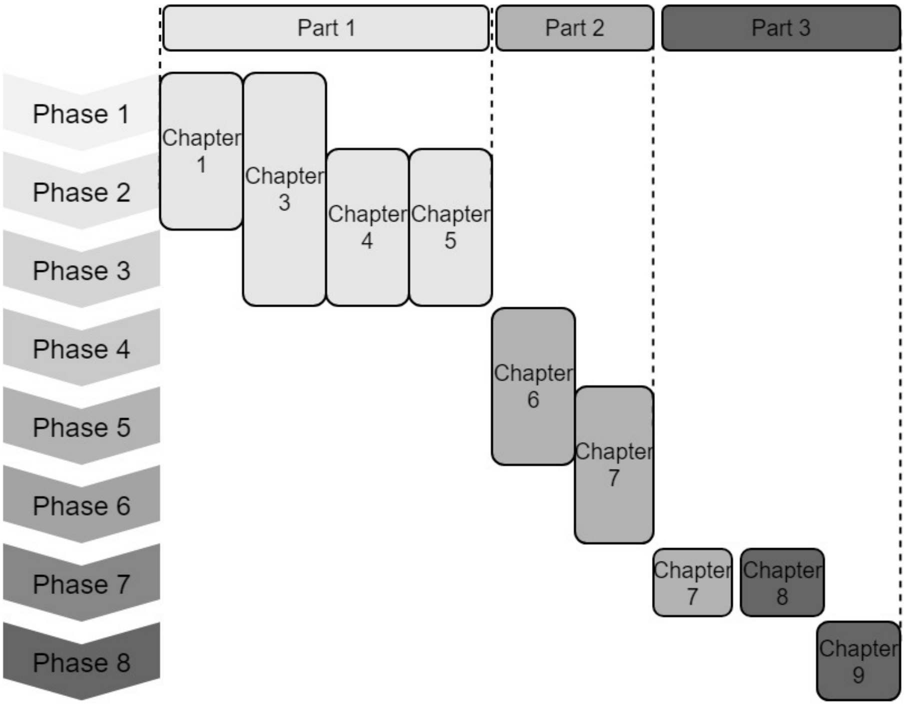

Figure 2.2: Overview of research design

2.3.1 Part 1

Before commencing with data collection, it is important to first clearly define the research problem and identify the primary objectives of the study. Chapter 1 clearly defines the problem, study objectives and provides background on the problem. The data sources identified within this study are industries, technology and sustainable development. Chapter 3 provides further insight into the problem and presents results of the systematic review.

A systematic review involves three key activities, namely: identifying and describing previously published relevant research, critically appraising the research methods and bringing together the aggregated findings into synthesis findings (ten Ham-Baloyi and Jordan, 2015). The systematic literature review was conducted using Scopus[1] and Google Scholar[2] as search platforms.

[1]https://www.scopus.com/
[2]https://scholar.google.co.za/

Systematic review limitations

The systematic literature review methodology has limitations that should be noted regarding the specific questions asked in the search. This study only included studies published in English, excluding several earlier studies conducted. Specific words were identified that return specifically to the search terms. Due to the lack of accessibility to certain studies across the world, only those accessible through Stellenbosch University were included.

Step 1: Identifying and describing previously published relevant research

By using the above mentioned search platforms, appropriate search terms were identified in order to retrieve the necessary literature. The search terms used in the systematic literature review were "technology", "South Africa", "Sustainable Development" and "industry type". "Industry type" can be seen in Table 2.1 and is presented one by one. The variety of industries found within the South African environment can be classified into three different sectors, namely primary, secondary and tertiary sectors (Clark, 1940; Fisher, 1939; Fourasti'e and Lutz, 1954).

Table 2.1: Industry type search terms (DRI, 2017)

Real estate service	Agriculture	Electricity	Water
Government service	Construction	Fishing	Mining
Community service	Manufacturing	Transport	Gas
Financial service	Accommodation	Forestry	Trade
Business service	Communication	Catering	Storage
Personal service	Social service		

Step 2: Critically appraising the research methods

Step 2 was carefully executed by assessing the resulting publications for their applicability and quality. The quality of the research was checked using the amount of citations each publication had and the citations in the publication. This was executed by retrieving the publications, reading the abstract and conclusions, and checking the relevance of the publications.

Step 3: Synthesising the research findings

The final key activity of the systematic literature review included data extraction and synthesis. The extracted data describes the technology currently in use within South African industries.

Chapter 4 provides the current available, new and emerging technologies that foster SD. It is further classified into separate technological categories, which technologies exist in each category and the opportunities they provide to improve and/or contribute towards SD and SDGs. Chapter 4 concludes with a discussion of how some technologies within certain categories may affect the South African environment in terms of SD and SDGs.

Part 1 of the research design concludes with the SD and SDGs, discussed in Chapter 5. This chapter provides an understanding of how SD is fostered and explains the SDGs with relevant agendas to the SDGs. Chapter 5 further describes the current state of South Africa in terms of SDGs and identifies current challenges and focus areas within South Africa.

2.3.2 Part 2

Chapter 6 evaluates the existing frameworks, approaches and models which exist within the field of technology transitioning and adoption. These evaluations created a deeper understanding of the existing frameworks, approaches and models and provided requirements for the developed framework. The design requirements are presented in chapter 6, and in chapter 7, the framework was developed and described. Based on part one of this study and the evaluations in chapter 6, a new framework was developed in chapter 7, namely "Industry and technology alignment with SDGs framework".

Part 2 includes the first phase of the validation process that was based on qualitative data that was gathered from field experts through semi-structured, open-ended interviews. The validation method was based on the subject matter expert process with an in-depth review of the framework and literature. Interviews were set up with field experts who received an explanation of the framework. Thereafter, a short questionnaire, using open-ended questions was administered to capture feedback from the experts.

2.3.3 Part 3

Chapter 8 entails the second phase of the validation process. The second phase of the validation process consisted of a case study that represents the research used to develop the framework and aims to present the reader with a theoretical argument.

The final chapter, chapter 9, concludes the study with a compact summary of the research conducted, the conclusions of the study, limitations experienced during the study and identifying future work recommendations.

2.4 Chapter 2: Conclusion

This chapter provided a short overview of the Grounded Theory and Conceptual Framework Analysis used in the present study. The Conceptual Framework Analysis method was further described and included the advantages of this method and how it was utilised to execute the research study. The research design consists of three parts, with part one comprised of phases one, two and three of the Conceptual Framework Analysis method. Phases four, five and six of the Conceptual Framework Analysis method is described in part two. The last part of the research design, part three, concludes the study with a validation process, recommendations and the conclusion of the study. Part 3 includes phases seven and eight of the Conceptual Framework Analysis.

Chapter 3

The role of technology in South Africa

This chapter presents a overview of the systematic review. It further presenst the systematic review that was performed in order to identify the technology used in the Socio-Technical system within South Africa and further explains how the technology is used.

Technology plays an undisputed role in modern society and is a key driver for innovation and sustainable business growth (Dolata, 2013). Technology also contributes (both positively and negatively) towards the (un)sustainability of modern-day production and consumption patterns (Smith and Stirling, 2008). However, it is commonly acknowledged that technology, in itself, has no power (Geels, 2002). Only when technology is effectively integrated with social systems, will it be able to fulfill its function within such a Socio-Technical (ST) system (Brent, 2015). This section of the study seeks to gather and analyse publications focused on the use of technology to facilitate Sustainable Development (SD), specifically in the South African context.

Key issues facing managers include understanding the link between technology and corporate strategy, technology diversification, and technology acquisition. Ultimately, managers are appointed to determine the most effective and efficient methods for meeting the technology development challenges necessary to survive in their respective industries (Jones et al., 2001).

3.1 Technology usage put into perspective

Research has shown how technology influences and ultimately changes ST systems (Blohmke, 2014). However, data concerning the role of technology in shaping and transforming ST systems in developing countries are insufficient. Changes in, and transitions of, ST systems can (and do) have a significant impact on the economic, social and environmental development of countries. Given the backdrop of the quest for SD and the role of technology when aiming to transition towards sustainability, questions such as 'how is technology implemented, managed and continuously improved within the context of SD in developing or emerging economies?' (Blohmke, 2014) arise.

According to Schot & Geels (2008), one of the key learning points for the use of technology to foster SD is that focus should not be on individual products and processes, but rather on ST systems and relations between the different levels that exist within such ST systems. A ST systems is a physical manifestation of the processes of development, which result from investment of capital, use of technical knowledge, application of human expertise, labour and operation of governing institutions (Walker et al., 2008).

The actors, institutions, organisations, and resources shape who reaps the benefits and who bears the costs and risks of these systems (Siddiqi and Collins, 2017). Additionally, operation optimisation has moved from focusing on a specific facility or organisation to the entire supply chain. This produces good service, maximum value and lowest cost (Schot and Geels, 2008). It means that shifting the focus to supply chains is contributing towards SD (Linton et al., 2007).

The main debate in SD argues for an eco-efficient approach in all countries in which technology-push strategies raise the level of efficiency by a factor 10 (Paredis, 2011). Due to the current unsustainability of production and consumption patterns, it is argued that future sustainability of ST systems is heavily dependent on technological innovation, which includes all devices, methods, processes, and practices. All of which can be used to provide the desired living standard without compromising the needs of future generations (Anadon et al., 2016; Brooks, 1980). However, according to Ahmadian (2008), experience of limitations in the diffusion of technological innovations is not limited to science and technology. These limitations are hard to overcome and are mostly found within the immobility of organisational, social and institutional systems incorporated with the technological systems (Ahmadian, 2008).

SD started to gain prominence when the International Union for the Conservation of Nature and Natural Resources presented the World Conservation Strategy (WCS) in 1980 with "the overall aim of achieving SD through the conservation of living resources" (IUCN, 1980). Since then, subsequent work has broadened to define SD as something that does not allow "inclusive well-being" to decline over time (Anadon et al., 2016).

Although man definitions of SD exist, the most frequently used definition of SD, namely "SD is development that meets the needs of the present without compromising the ability of future generations to meet their own needs" from "Our Common Future", also known as the Brundtland Report (Brundtland and Khalid, 1987). Nevertheless, the concept of sustainability continues to challenge us to consider future costs, implications and the benefits of our actions, the rights to resources and the shaping of consumer needs given environmental limits (Bell et al., 2011).

Organisations today have used technology to improve the logistics of products, services, staff retention, empowerment (Iwu and Benedict, 2013) and much more. The success of applying technologies to organisations depends on the co-ordination of technology and the alignment to incorporate goals and capabilities, with the purpose of achieving competitive advantage (Hipkin and Bennett, 2003; Leonard-Barton and Deschamps, 1988; Martinsons and Schindler, 1995). Various technologies have been successfully implemented into different business sectors. However, a small margin of technologies are successful in their respective fields. Information and Communication Technologies (ICT) remain the bedrock for the development of various sectors (Akinyede and Adepoju, 2010), while organisations implement internet technology in order to remain competitive (Iwu and Benedict, 2013).

In order for this study to provide meaningful results, it focusses on industries within the South African environment. Three types of sectors identified by Fourasti'e & Lutz (1954), Fisher (1939) and Clark (1940) are the primary (business concerned with obtaining or providing natural raw materials), secondary (converts raw materials into products) and tertiary (providing a service) sectors. These sectors consist of multiple industries as shown in Table 3.1.

Within these three sectors of South Africa the following industries are found: agri-culture, forestry and fishing; mining; manufacturing; construction; electricity, gas and water; transport, storage and communication; trade, catering and accommodation; finance and business services; community, social and personal services (DRI, 2017). Each industry comprises its own technologies and challenges regarding new technology to foster SD.

Table 3.1: Industries divided into three sectors

Sector	Industry
Primary sector	Agriculture; forestry; fishing; mining; gas
Secondary sector	Manufacturing; construction; electricity
Tertiary sector	Water; trade; accommodation; catering; transport; storage; communication; financial, business and real estate service; community, social, personal and government service

Research only recently started to find evidence of a more balanced approach for SD. Research on ST sustainability transitions revealed that the focus has shifted to the co-evolution of technology and society (Paredis, 2011). According to Paredis (2011) SD can be achieved without making fundamental changes within the present structures of society.

Brundtland & Khalid (1987) offer the objectives for SD policies. These include policies that focus on reviving growth, reorienting technology and managing risks within the context of SD (Brundtland and Khalid, 1987).

3.2 Justification for systematic review

The methodology used in this study is based on the systematic literature review as described in Chapter 2. A systematic review is defined as "a review of a clearly formulated question that uses systematic and explicit methods to identify, select, and critically appraise relevant research, collect and analyse data from the studies that are included in the review" (ten Ham-Baloyi and Jordan, 2015). A systematic review differs from a conventional review through the use of a research protocol. Readers can assess its rigour, completeness and replicability. A systematic review reduces the effects of chance and increases the legitimacy and authority of the evidence found (Tranfield et al., 2003).

3.2.1 Advantages and disadvantages

Advantages (Jackson, 2004; ten Ham-Baloyi and Jordan, 2015; Tranfield et al., 2003):

i. The systematic review can be replicated;
ii. Clear and precise methods are used to identify relevant studies;
iii. Systematic review is a rigorous method; and
iv. Systematic review shows transparency in the methods used to generate conclusions.

Disadvantages (Jackson, 2004; ten Ham-Baloyi and Jordan, 2015; Tranfield et al., 2003):

i. The process is time consuming;
ii. Infrastructure and access constraint occur if there is limited availability to electronic database(s);
iii. A large amount of literature can lead to endless possibilities; and
iv. Insufficient amounts of studies can restrict or limit the process of synthesising the literature.

3.3 Conducting the systematic review

Systematic review involves three key activities: identifying and describing previously published relevant research, critically appraising the research methods and synthesising the aggregated findings (ten Ham-Baloyi and Jordan, 2015).

3.3.1 Step 1

The first key activity of the systematic review was conducted using Scopus[1] and Google Scholar[2] as search engines. The results of each individual search is represented in Table 3.2 and Table 3.3. Due to the ease of using of Scopus, there were three searches (S-1, S-2 and S-3), whereas only two searches (G-1 and G-2) using Google Scholar was performed. Each column presents an in-depth result of the previous column, with the initial search found in Column "S-1". The initial

[1] https://www.scopus.com/
[2] https://scholar.google.co.za/

Table 3.2: Scopus search

Search terms	S-1	S-2	S-3
“Agriculture” AND “Technology” AND “South Africa”	128	70	23
“Forestry” AND “Technology” AND “South Africa”	44	11	2
“Fishing” AND “Technology” AND “South Africa”	9	2	2
“Mining” AND “Technology” AND “South Africa”	311	39	16
“Manufacturing” AND “Technology” AND “South Africa”	212	32	12
“Construction” AND “Technology” AND “South Africa”	260	37	10
“Electricity” AND “Technology” AND “South Africa”	308	101	29
“Gas” AND “Technology” AND “South Africa”	360	70	10
“Water” AND “Technology” AND “South Africa”	617	141	25
“Trade” AND “Technology” AND “South Africa”	208	36	9
“Accommodation” AND “Technology” AND “South Africa”	12	3	0
“Catering” AND “Technology” AND “South Africa”	10	1	0
“Transport” AND “Technology” AND “South Africa”	153	30	8
“Storage” AND “Technology” AND “South Africa”	154	21	0
“Communication” AND “Technology” AND “South Africa”	763	107	25
“Financial service” AND “Technology” AND “South Africa”	17	3	2
“Business service” AND “Technology” AND “South Africa”	6	1	0
“Real estate service” AND “Technology” AND “South Africa”	2	0	0
“Community service” AND “Technology” AND “South Africa”	6	3	2
“Social service” AND “Technology” AND “South Africa”	3	0	0
“Personal Service” AND “Technology” AND “South Africa”	0	0	0
“Government service” AND “Technology” AND “South Africa”	18	5	3

search was executed by searching for the search terms within the title, abstract and key words of articles. The code was as follows: TITLE-ABS-KEY(Search Terms).

The Scopus search engine was then used to search for the search terms, Sustainability OR SD, within the title, abstract and key words of publications. The results can be found in column “S-2” and the code for each search was as follows: (TITLE-ABS-KEY(Search Terms)) AND (“Sustainability” OR “SD”). The second platform, Google Scholar, was used to expand the search for publications. The initial search “G-1” was conducted using the search terms in column one of Table 3.3.

3.3.2 Step 2

The second key activity was carefully executed by assessing the results for their applicability and quality. In the last columns of Table 3.2 and 3.3 are the number of publications that were found to be useful, applicable and of acceptable quality. The quality of the research was ascertained by checking the amount of citations each publication had and the references cited within the publication itself. This was executed by retrieving the publications, reading the abstract and conclusions, and checking for relevance. After completion of this activity, 178 publications were

Table 3.3: Google Scholar search

Search terms	G-1	G-2
Agriculture Technology “South Africa”	4	3
Forestry Technology “South Africa”	2	1
Fishing Technology “South Africa”	0	0
Mining Technology “South Africa”	4	3
Manufacturing Technology “South Africa”	3	2
Construction Technology “South Africa”	3	2
Electricity Technology “South Africa”	0	0
Gas Technology “South Africa”	1	0
Water Technology “South Africa”	6	3
Trade Technology “South Africa”	15	10
Accommodation Technology “South Africa”	0	0
Catering Technology “South Africa”	0	0
Transport Technology “South Africa”	2	1
Storage Technology “South Africa”	1	1
Communication Technology “South Africa”	82	17
Financial service Technology “South Africa”	1	1
Business service Technology “South Africa”	0	0
Real estate service Technology “South Africa”	0	0
Community service Technology “South Africa”	0	0
Social service Technology “South Africa”	0	0
Personal Service Technology “South Africa”	0	0
Government service Technology “South Africa”	10	5

found using Scopus and 49 publications using Google Scholar were sourced, respectively.

3.3.3 Step 3

The final key activity of this systematic review included data extraction and synthesis which is presented in the next section. The next section describes the technology currently in usage within the South African industry. The following section is divided into three sub-sections, describing the three business sectors highlighted earlier in this Chapter.

3.4 Technology in the South African Socio-Technical system

This section discusses the use of technology in different industries to facilitate SD in the South African context. The systematic review revealed that there is currently no single technology which fits all industries, nor is there any technology in the right position to plug-and-play into all industries. However, ICT consist of an extended list of components that are, or can be, implemented in South Africa to facilitate SDs. ICT is currently being used in all business sectors. However, manufacturing, transport, and, services within the financial and business sectors have been showing the most implementation of these technologies.

ICT include the use of internet, wireless networks, mobile phones, and other communication mediums. It entails a list of technologies that continue to grow (Christensen, 1997; Rouse, 2017). ICT can be defined as a combination of manufacturing and service industries, which capture, transmit and display data and information by means of electronic transfer (Aldemir and Gülcan, 2004). An ICT system consists of six components, namely data, hardware, software, information, procedures and people (Rouse, 2017).

In order for organisations, governments and countries to implement ICT successfully, the Technology Acceptance Model (TAM) can be used across all levels in order to achieve successful adoption of technologies. TAM is used to explain and predict the individual's acceptance of technology. A number of studies used the TAM to explain and predict the adoption of technologies in the ST systems successfully (Bruner and Kumar, 2005; Igbaria and Tan, 1997; Luarn and Lin, 2005; Moon and Kim, 2001; Taylor and Todd, 1995; Venkatesh and Morris, 2000; Wentzel et al., 2013; Wu and Wang, 2005).

3.4.1 Primary sector

The agri-culture sector in South Africa plays a critical role in employment creation and poverty reduction. Thus, the correct technologies must be implemented in order to facilitate reductions in poverty and increase employment (Taruvinga et al., 2017). The present review revealed that there are currently only a small number of technologies used in agriculture. Currently, the use of ICT is applied in this sector to support the supply chain in ensuring constant flow of information.

One challenge facing many farmers is uneducated workers. There is a small variety of technology that can be implemented to assist the uneducated workforce. While small-holding farmers (small plots of land for producing crops for personal and local use) still struggle to connect with technology, these farmers have been innovative by implementing agri-logistics that minimise the transportation of products to and from their farms. Most of these innovative strategies implemented by smallholding farmers are unsustainable and could easily be achieved through the use of other strategies (Perret and Stevens, 2006). However, such innovative ideas and implementation strategies on a small scale could provide solutions and testing results for current situations.

ICT systems provide organisations with the ability to connect and manage uneducated workers which exist mostly in the primary sector. One such example of ICT is logistics, whereby multiple farmers are connected to one system, enabling each farmer to transport the same load for less. Alternatively, farmers make use of service providers in the transport sector. By connecting people through the ICT system, farmers have the potential to eliminate the middleman. As a result, they receive higher profit margins, resulting in providing the customer with the same product for less. ICT improve the marketplace both locally and internationally, while also providing them with the opportunity to sell products at lower market prices. Through such systems and technology to connect farmers with customers, services become easy and hassle free.

Large scale farmers make use of other technologies such as Participatory Technology Development and Satellite-Based Augmentation System (SBAS). Participatory Technology Development is used to develop more sustainable farming systems (van Veldhuizen et al., 1997). SBAS provides management of information related to their assets and provides management with optimised logistics (SBAS Africa, 2017).

Both technologies could reduce cost and facilitate SD in South Africa if correctly implemented and managed. However, this is costly and skills in management of these technologies need to be transferred to users. The SBAS technology provides the forestry industry with similar abilities, resulting in management making more informed decisions. SBAS also provides logistics in the form of optimal routes for transportation and route optimisation for assets in operation which could help smallholding farmers.

Agroforestry involves the integration of trees into farming systems in ways that create an agroecosystem succession, similar to that in natural systems (MEA (Millennium Ecosystem Assessment), 2005). At the same time, agroforestry is a promising land-use practice to maintain or increase agricultural productivity while preserving and improving agricultural land fertility (Zerihun et al., 2014). Agroforestry technologies have been shown to have the potential for improving productivity and the livelihoods of rural farmers (Garrity, 2006; Zerihun et al., 2014). However, very little effort has been made to promote agroforestry technologies in South Africa irrespective of their vast potential in the country. Despite the increasing realisation of agroforestry as an environmentally and economically suitable land-use practice, the adoption of agroforestry technologies has been very slow across all sub-Saharan African countries (Franzel and Scherr, 2002; Mafongoya et al., 2006; Zerihun et al., 2014).

Fishing technology has evolved from simple harpoons and hooks to industrial trawlers. After decades of assuming that seafood resources are inexhaustible, recent raised that advanced fishing technologies may have a detrimental impact on stocks and ecosystems have been raised. The last century has seen advances in fishing technology targeted as a major contributor to current over-exploitation of fish stock and as such, this form of technology has been suggested to be highly unsustainable (Kennelly and Broadhurst, 2002).

Technology has changed the mining industry and the way in which large mining sites operate. The mining industry has had a significant increase in the degree of automation, providing larger and more efficient equipment, furnaces and beneficiary plants (Bartos, 2007; Filippou and King, 2011; Paton et al., 2016). According to Leeuw & Mtegha (2016) there are multiple categories of technology available to the mining industry. There are 12 nodes of input mining technology (various forms of mining-related technology). The different forms of technology in each class and in which category they fall (Artefact, Machine, Software and Mining Service Technology Category) is classified by Leeuw & Mtegha (2016).

Although electricity is its own industry, many other industries depend on electricity to keep their processes running. Mining is one of the dominant industries contributing to energy consumption. Hence, there is unique opportunities available for mining to investigate the use of renewable energy technologies, thereby reducing greenhouse gas emission (Glaister and Mudd, 2010). Renewable energy will not fully meet electricity needs, although it will provide for a significant reduction in these needs, as well as gas emission (Glaister and Mudd, 2010).

3.4.2 Secondary sector

Manufacturing which uses various technologies in the ICT system, is able to produce almost near-zero downtime (Nyanga et al., 2012) with the help of technology. In their operations, technology has been used to promote a Just-in-Time factor that reduces cost and optimises the supply chain. Technologies have made logistics for manufacturers easier by connecting data and live-stream distribution and making online marketing and sales more fluent, efficient and effective (Chisango and Lesame, 2014; Heeks, 2002; Rhodes, 2009). These technologies are able to plan resources, and monitor and schedule processes which control products. This enables management to produce products without any or minimal employees and run for almost twenty-four hours, seven days a week (Amojee and Steyn, 2015).

Connecting the supply chain through ICT makes communication between supplier and customer easier and improves the customer-supplier relationship (Mashigo et al., 2015). New technological innovations enable the manufacturing assets to push notifications with information regarding maintenance to necessary service providers. This service leaves the customer satisfied and the organisation's supply chain functioning more effectively (Barnes et al., 2001). ICT systems give manufacturers and customers the ability to track their products in real-time, enhancing the customer experience. Customers can make necessary changes through the ICT system, making the supply chain more flexible. ICT facilitates organisations to market and sell their product to a wider range of customers through internet technologies.

Construction is a complex and time-consuming process, which could be managed by technology, if implemented correctly. ICT enable this complex system to communicate and provide insights into the project time line. ICT provides a communication band to all stakeholders and automates project management. This process makes it easy to change materials and quantities (Windapo and Cattell, 2013). Additionally, it provides interaction between stakeholders and customers, resulting in better customer service. Nonetheless, limited financial resources and an uneducated workforce make it almost impossible to adapt the necessary technology and as such, contribute to a lack of new technological innovations (Windapo, 2014).

The electricity industry and the use of technology within this industry is one of the most advanced. The electricity industry consists of various types of technology, ranging from ICT to electricity generation. Clean energy has become more popular in developing countries for two reasons mainly. Firstly, the diversification of energy supplies emits less, improving the environment (Thiam et al., 2012). Secondly, the main renewable sources of energy include hydro power, solar, wind, biofuel and geo-thermal (Mathu, 2014). Multiple plants have been created across South Africa and provide electricity to the grid. The government considers the use of renewable energy a contributor to SD (Winkler, 2007).

3.4.3 Tertiary sector

The transportation industry is certainly one of the most complex systems. However, it also implements technology to improve processes. The Information Technology Systems enable the sector to excel by providing traceable goods, online-inventory management, distribution management, billing and customer communications (Baxter and Sommerville, 2011).

ITS combines processing with control, boosting transport efficiency, security and sustainability (Dlodlo, 2015). It pushes notifications to necessary service providers in case of emergencies, providing customers with peace of mind. The ITS provide customers and management with real-time tracking and makes marketing and sales less complex for the respective organisation. Furthermore, it promotes a bigger marketplace where one can buy and sell products and services.

In the trade and retail sector, Radio Frequency Identification has been extensively researched and barriers such as high cost, skills shortage and difficulties with implementation, among others, have been identified (Upfold and Liu, 2010). Technologies have been developed to minimise energy consumption and facilitate SD (Nhamo, 2014). ICT systems are currently widely used to service customers. According to Rhodes (2009) Radio Frequency Identification has been poorly implemented and needs to be controlled to remain sustainable.

ICT systems in the trade and retail sector are mainly operating in the logistics, marketing, sales and services sectors, enabling these organisations to connect with real-time logistics and online inventory management (Yusuf et al., 2017). The use of this technology used throughout the marketing department enables the company to reach international marketplaces with ease. Sales are more effective and efficient and the after-sales service enables the customer to connect with the organisation at any given time and any given location (Mbuyisa and Leonard, 2015).

Technology innovation and adoption has affected the services sector. Thus, technology innovation has forced financial and business service industries to adopt new methods of delivering services to customers. Technology in various forms have become competitive and are now a major challenge that impact firms in current markets (Hove and Masocha, 2014). The services market has grown from local to national and international markets, as technology has been enhanced accordingly. ICT systems have moved the industry from face-to-face interaction towards services at any given time and any given location. It connects the service provider and consumer, enabling quick response times, less travel time for both parties and better customer satisfaction.

Technology has made it easier for service providers to bypass logistics (Wentzel et al., 2013) and even easier to market services online using internet technologies through ICT (Schlenker and Crocker, 2003). New technologies result in new products and services for consumers, improved existing products, better customer services and often, lower prices. When customers experience one negative aspect, it regularly leads to switching and substituting of existing products with new ones (Boone and Kurtz, 1992; Hove and Masocha, 2014).

ICT has changed the way services are delivered. Accommodation became easier through the use of such technologies by connecting the owner with clients. Current clients can advise future clients on their experience, whether good or bad. This is similar to the catering industry where feedback is key to good service (Roux and Marais, 2011).

Storage, newly added to the ICT technologies portfolio, is used to provide additional space for those who would share storage space and help others in need of extra space to store any form of valuable assets (Gajjar and Mondol, 2016).

While South Africa's government has made use of some technology innovations (Heeks, 2002), the lack of management and maintenance causes these processes to be less productive. Policies set by the South African government give some sense of calm. Yet, rural areas remain disconnected from the rest of South Africa (Chisango and Lesame, 2014).

Water management has gained increasing attention around the world and technologies regarding water management are widely spread and used (Nhapi and Gijzen, 2005). Management of water has a variety of processes that include treatment of drinking, industrial, sewage or waste-water, management of resources, flood protection, irrigation, and the water table. Technology used in the treatment and management of water include ICT systems to manage resources and maintain current implemented technologies (Karlberg et al., 2007). The lack of correctly implemented systems is the main contributor faulty water management in developing countries (Barron et al., 2015).

Studies have found that implementing technology into healthcare and education with the help of ICT increases the human-development index more rapidly in developing countries (Gholami et al., 2010). Opportunities for the economy to develop are also increased (Gholami et al., 2010). South Africa has excelled in this area, with an increase in e-health (supported by insurance companies) on mobile devices aimed to reach people before situations become critical (Coursaris et al., 2008). However, technology in the education sector is still under-developed due to numerous unresolved barriers (Chisango and Lesame, 2014).

ICT systems have changed the services industry. Yet, the social and personal service industry still struggles to adapt. Limitations such as poverty, rural areas and uneducated citizens have held South Africa back from innovation (Thabrew et al., 2009). ICT systems have been used in government, but due to incorrect structural implementation, management and maintenance, these systems have not been working at optimal effectiveness and efficiency (Johnston et al., 2015).

The private sector has helped the public sector in innovative healthcare systems. ICT systems have been supported by various platforms such as insurance organisations. ICT provides a platform for citizens and service providers to communicate around the clock and as such the logistics, marketing and sales have become less complicated in these sectors (Schönfeldt et al., 2018).

3.4.4 Results

Technology which improves a company's ability to produce products and services and that corresponds to a client's needs, is good technology. In other cases, however, it may well be a waste of money (Schlenker and Crocker, 2003). The three main factors that need to be accounted for when managing technology are (1) the skills of personnel in the organisation, (2) how complex the new technology is and (3) whether the new technology can be used to its full potential without depending on the technology supplier (Hipkin and Bennett, 2003).

The fourth industrial revolution, the Internet of Things (IoT) is able to adapt to any industry sector. Research on the fourth industrial revolution is limited. However, developed countries are implementing such systems and have shown tremendous improvements. South Africa, as a developing country, has to catch up to these trends. Drastic changes to improve the use of technology in supply chains and move towards sustainability must be implemented (Dlodlo, 2015).

The results from present study highlight that organisations striving to achieve better performance through the implementation of technology should align these technologies with the organisation and sustainability goals. This involves making the right management decisions and being capable of managing and maintaining the relevant technology needed. Organisations achieve this through leadership that fosters staff development, empowers employees to be innovative, and continuous improvement along the supply chain towards SDs. Through the right implementation of technology, organisations can embrace the benefits of economic growth, skilled employees and improved quality of products and services.

3.5 Chapter 3: Conclusion

This chapter investigated the role of technology in SD in South Africa where sustainability is developing through the use of technology. However, some crucial limitations that restrict this action are poverty, unemployment, uneducated workforce and the lack of adequate management. The results of the present study revealed that Information and Communications Technologies (ICT) are implemented in most sectors to pursue the connection of supply chain activities and customer satisfaction.

Chapter 4

The unused, new and emerging technology to foster sustainable Socio-Technical systems

This chapter provides information regarding the available technologies that foster Sustainable Development (SD) and how these can change the South African environment in terms of SD.

"*Great technology potential has been accompanied by equally great concerns about social, political, economic and environmental impacts*" (p. 119) (UN, 2016*a*).

Scientists and many others see technology as a major factor that can help to meet Sustainable Development Goals (SDGs) (UN, 2016*a*). The big rule of SD for technology enhancements and innovations is to emphasise resource productivity and the amount of value extracted per unit of resource, rather than technologies for increasing the resource throughput itself (Daly, 1990). The SDG agendas (described in the next chapter) provide tools which could direct and guide future developments through providing the community with economic instruments, legislative measures and consumer pressures. These are aimed at achieving technological changes such as recycling, waste minimisation, substitution of materials, changed production processes, pollution control and more efficient usage of resources (Beder, 1994). Many countries find ways of 'technological fix' response to pollution instead of replacing the technology creating the pollution (Beder, 1994; Clarke, 1974). However, Nathan (2018) states that the right technologies are available to make development sustainable, but the challenge is deploying them in the right way.

4.1 Technologies that foster Sustainable Development

In the SD 2016 Report (UN, 2016*a*), the question of "Which technologies and what level of their performance and deployment will be most crucial until 2030?", was asked. Scientists from various field were asked to provide inputs and the results were summarised categories namely:

biotechnology, digital technology, nanotechnology, neurotechnology, green technology and other technologies. These categories are further described in this section.

4.1.1 Biotechnology

These technologies span various departments such as health, materials, environment and pharmaceuticals. It provides information and help regarding environmental issues, medicine and pharmaceuticals, infectious diseases and modifications of food crops. Biotechnologies cause irreversible change to human health and the environment if inappropriately managed and used. Thus, effective policies and frameworks are necessary to control all stages of biotechnology's life cycle. Table 4.1 summarises the current emerging technologies in the biotechnology field, mostly in human health, the opportunities of support provided by the SDGs and potential threats of these technologies (UN, 2016*a*).

Table 4.1: Crucial Biotechnology emerging for the SDGs until 2030(UN, 2016*a*)

Crucial emerging technology for the SDGs until 2030	Opportunities in all SDG areas	Potential threats
Biotechnology, genomics, and proteomics; gene-editing technologies and custom designed DNA sequencing; genetically modified organisms (GMO); stem cells and human engineering; bio-catalysis; synthetic biology; sustainable agriculture technology	Food crops, human health, pharmaceuticals, materials, environment, fuels.	Military use; irreversible changes to health and environment

4.1.2 Digital technology

Digital technology is rapidly advancing. While some gaps in the digital world have closed, others continually open with the introduction of new digital technologies. Some of these includes the fifth generation (5G) mobile phones (with faster data connections), "Internet of Things" (IoT) (interconnects physical objects to internet infrastructure), 3D printers (local manufacturing of copy right components and products), "Big Data" (transforming the way to do business) and wireless sensor networks. All of these technologies connect to one another in some way, which raises concerns about the impact these technologies have on people's privacy, freedom, security, safety and development (UN, 2016*a*).

Two of the most crucial emerging fields in the digital technology department are the use of Big Data and IoT, where through the use of these datasets and internet-connected sensors. Governments receive the necessary information about urban and rural developments within the country. However, it can also introduce new risks such as those of data privacy and security. These technologies provide a platform for SD (in the fields of health, agriculture, food security, sustainable urbanisation, etc.) at low cost through cloud computing platforms and enables local communities to innovate without significant capital investment. In order to limit the security and privacy of citizens, the national government should consider limitations of big data and IoT. Big Data and IoT could also serve existing national development planning and regulatory frameworks for securing the rights of citizens with respect to privacy and security, and strengthen human capital and the larger ecosystem to effectively use these tools. (UN, 2016*a*)

Table 4.2: Emerging digital technologies for the SDGs until 2030 (UN, 2016*a*)

Crucial emerging technology for the SDGs until 2030	Opportunities in all SDG areas	Potential threats
Big Data technologies; Internet of Things; 5G mobile phones; 3-D printing and manufacturing; Cloud computing platforms; open data technology; free and open- source; Massive open online courses; micro-simulation; E-distribution; systems combining radio, mobile phone, satellite, GIS, and remote sensing data; data sharing technologies, including citizen science-enabling technologies; social media technologies; mobile applications to promote public engagement and behavioural change; pre-paid system of electricity use and automatic meter reading; digital monitoring technologies; digital security technology.	Development, employment, manufacturing, agriculture, health, cities, finance, absolute "decoupling", governance, participation, education, citizen science, environmental monitoring, resource efficiency, global data sharing, social networking and collaboration	Unequal benefits, job losses, skills gaps, social impacts, poor people cannot afford the high prices; global value chain disruption; concerns about privacy, freedom and development; data fraud, theft, cyber-attacks

4.1.3 Nanotechnology

Nanotechnology has high expectations in decentralised water and wastewater treatment and desalination. The nanotechnology field withholds promising potential for SD in energy, water, chemical, medical and pharmaceutical industries. Big challenges such as negative effects on the environment and human health may affect the course of the field. However, with effective policies and frameworks, nanotechnology can offer a promising future. Table 4.3 summarises the emerging technologies in the field of nanotechnology, provides the opportunities available to support the current SDGs and the potential threats to the field (UN, 2016*a*).

Table 4.3: Emerging nanotechnologies for the SDGs until 2030 (UN, 2016*a*)

Crucial emerging technology for the SDGs until 2030	Opportunities in all SDG areas	Potential threats
Nanoimprint lithography; nanotechnology applications for decentralized water and wastewater treatment, desalination, and solar energy (nanomaterial solar cells); promising organic and inorganic nanomaterials, e.g., graphene, carbon nanotubes, carbon nano-dots and conducting polymers graphene, perovskites, Iron, cobalt, and nickel nanoparticles, and many others	Energy, water, chemical, electronics, medical and pharmaceutical industries; high efficiencies; resources saving; CO2 mitigation	Human health (toxicity), environmental impact (nanowaste)

4.1.4 Neurotechnology

Neurotechnologies include various technologies such as, amongst others, smart technologies, artificial intelligence, speech recognition. According to the Sustainable Development 2016 Report (UN, 2016*a*), smart technologies will be crucial technologies and will become a part of our daily lives to strive for sustainability. Automation and artificial intelligence have gained attention over the past couple of years and shown promising leads for SD. However, the potential consequences on employment are emerging areas of concern in need of further investigation. The expansion of the neurotechnology field is likely to affect healthcare, education, privacy and cyber security, and energy and environment management.

In South Africa, neurotechnologies have been proven to work. For example, smart electricity metering enables the government to manage the losses of electricity due to theft and smart water metering enables governing officials to identify water users exceeding the limit or to identify possible leaks in water pipelines (Kramers et al., 2014). Table 4.4 summarises the crucial emerging technologies in the field, opportunities for supporting SDGs and potential threats to the neurotechnology field, as outlined in Table 3.3 of the 2016 Sustainable Development Report (UN, 2016*a*).

Table 4.4: Emerging neurotechnologies for the SDGs until 2030 (UN, 2016a)

Crucial emerging technology for the SDGs until 2030	Opportunities in all SDG areas	Potential threats
Digital automation, including autonomous vehicles (driverless cars and drones), IBM Watson, e-discovery platforms for legal practice, personalisation algorithms, artificial intelligence, speech recognition, robotics; smart technologies; cognitive computing; computational models of the human brain; meso-science powered virtual reality.	Health, safety, security (e.g., electricity theft), higher efficiency, resource saving, new types of jobs, manufacturing, education.	Unequal benefits, deskilling, job losses and polarization, widening technology gaps, military use, conflicts.

4.1.5 Green technology

Green technology can be referred to as a technology that is environmentally friendly or environmentally sound (Cloete et al., 2014). The use of existing or new nanotechnology, biotechnology, and digital technology can be deployed as green technologies to reduce non-renewable resource use and to utilise and support the ecosystem process. These technologies (old or new) can be included for re-manufacturing, technology life-cycle extension and for recycling (UN, 2016a).

Green technology is a form of technology that can be utilised in any business sector, ranging from agriculture to government processes. Table 4.5 outlines which green technologies are emerging in sectors, opportunities to support SDGs and future threats.

Table 4.5: Emerging green technologies for the SDGs until 2030 (UN, 2016*a*)

Crucial emerging technology for the SDGs until 2030	Opportunities in all SDG areas	Potential threats
Circular economy: technologies for re-manufacturing, technologies for product lifecycle extension such as re-use and refurbishment, and technologies for recycling; multifunctional infrastructures; technologies for integration of centralized systems and decentralized systems for services provision; CO2 mitigation technologies; low energy and emission technology. **Energy**: modern cookstoves with emissions comparable to those of LPG stove; Deployment of off-grid electricity systems (and perhaps direct current); mini-grids based on intermittent renewables with storage; advances in battery technology; heat pumps for space heating, heat and power storage and electric mobility (in interaction with off-grid electricity); smart grids; natural gas technologies; new ways of electrification; desalination (reverse osmosis); small and medium sized nuclear reactors; biofuel supply chains; solar photovoltaic, wind and micro-hydro technologies; salinity gradient power technology; water saving cooling technology; LED lamps; advanced metering. **Transport**: integrated public transport infrastructure, electric vehicles (e-car and e-bike), hydrogen-fueled vehicles and supply infrastructures. **Water**: mobile water treatment technology, wastewater technology, advanced metering infrastructure. **Buildings**: sustainable building technology, passive housing. **Agriculture**: Sustainable agriculture technology; Innovations of bio-based products and processing, low input processing and storage technologies; horticulture techniques; irrigation technologies; bio-organometallics which increase the efficiency of biomimetic analogs of nitrogenase. **Other**: Marine Vibroseis, artificial photosynthesis	Environment, climate, biodiversity, sustainable production and consumption, renewable energy, materials and resources; clean air and water; energy, water and food security; development, employment; health; equality	New inequalities, job losses; concerns about privacy, freedom and development

4.1.6 Other technologies

This subsection discusses technologies that do not fit into a specific field or are in such an early form of development that its own unique field cannot yet be identified. These technologies can be identified as assistive technologies for people with disabilities, social technologies that are minor or used in single user mode, geo-engineering technologies (e.g. for iron fertilisation of oceans), new mining/extraction technologies (e.g., shale gas in oceans, polar, glacier zones) and deep-sea mining technologies. There are countless opportunities for these types of new innovative technologies in development, health, environment, climate change mitigation and resource availability.

However, with any technology comes challenges and threats such as pollution, inequalities and conflict (UN, 2016*a*).

4.2 Technologies that can help South Africa foster Sustainable Development

In developing countries, considering the implementation of new technology can be highly complex. Many factors play a role in deciding how each technology is used and if the population will adapt to them. Identifying where South Africa lies on the technological curve is a crucial part of identifying old or new technologies for implementation. South Africa is a diverse country with a wide span of cultural and economic differences. South Africa is one of the leading research and innovation hubs. Nonetheless, the country fails to innovate technologies that can solve current and future problems within society, government and private sectors.

In order for South Africa to adapt to new technological advancements, a new view is required on how to learn, implement, operate and sustain human information and knowledge systems. The relation should be understood on the functioning of social ecological systems in the organisation of science, education and policy (Tàbara, 2013). Developing countries can benefit from open knowledge systems or open innovation, which is a more recognisable term. Open innovation is relatively new and refers to people collaborating freely across organisations, disciplines and borders to solve problems (Ockwell et al., 2014).

According to the 2016 Sustainable Development Report (UN, 2016*a*), achieving electrification of households, small urban (including rural business) and small agriculture holders in developing countries is achievable. This provides the agriculture sector with options such as mechanising activities. With the help of electrification, small and medium nuclear reactors, and mini-grids development based on renewable energy, the possibility of expansion of various technologies would be faster and IT for education deployed in remote areas.

Open source innovation can take place with the expansion of electrification of developing countries and could reach the rural developments faster. Open innovation can enable small urban and rural businesses to excel by using technology retrieved from open innovation and adapting these technologies to their specific needs. The open innovation initiatives are designed so that various people of different backgrounds can decide, produce and validate in partnership in different social ecological contexts in which specific needs and demands are to be fulfilled (Leach et al., 2013). The open innovation system enables continuous feedback that encourages others to learn and modify behaviours and practices (Mvelase et al., 2014; Tàbara, 2013; Tàbara and Chabay, 2013).

Based on the above identified technologies in different fields, some technologies may excel in developing countries and some may take time and improvements to reach optimal space for implementation. Biotechnology is a field that lacks within the borders of South Africa due to the weak infrastructure of health systems, lack of personal skills and lack of investment within the health department (UN, 2016*a*). According to the 2016 Sustainable Development Report (UN, 2016*a*), there have been a growing number of countries using web-based technologies for health-data reporting. These technologies are beneficial for the health industry because web-based technologies enable the industry to improve real-time availability, use and analysis of facility-based statistics.

The digital technology field is an interesting field in South Africa where Small and Medium Enterprises show great interest in this technological field. Numerous Small and Medium Enterprises have identified the need for these technologies such as Big Data and IoT which are currently being implemented in various industries. South Africa has shown great innovation and usage ideas in the technology field of 3D printing and manufacturing, cloud computing platforms, social media technologies, mobile applications to promote public engagement and behavioural change, pre-paid systems of electricity use and automatic meter reading, digital monitoring technologies and digital security technology (Gorejena et al., 2016; Mvelase et al., 2014; Windapo and Cattell, 2013).

One of the technological fields that could be beneficial to all sectors within South Africa is that of nanotechnologies. These technologies can be implemented in various companies such as decentralised water and wastewater treatment, desalination, and solar energy (nano-material solar cells) (Mwabi et al., 2011; Western Cape Government, 2011). This could enable cheaper processes that lead to wider availability in order to address social needs and make it easier to provide for the basic needs of the South African population. The neurotechnology field (which includes the digital automation, artificial intelligence, speech recognition, and robotics) which may attract and influence the private sector to become more efficient and effective in product and services delivery. The neurotechnology field is broad and can be implemented in most, if not all sectors within the South African environment and beyond to ensure inclusivity of all people (Qu et al., 2010).

Green technology is widely used within South Africa and throughout the rest of the world (Cloete et al., 2014). Within the green technology field, emerging technology can be categorised into five main categories namely: circular economy, energy, transport, water, buildings, and agriculture. The circular economy offers technologies for re-manufacturing or re-use and refurbishment, which is most likely to provide the previously marginalised individuals the opportunity to obtain technologies that can transfer new skills. By enabling the availability of technology to rural areas, new pathways open to developing countries by improving skills in individuals.

Various studies on off-grid electricity systems and mini-grids based on intermittent renewable with storage have shown both advantages and disadvantages (Brent and Rogers, 2010; Lubkoll et al., 2005). South Africa has the ability to learn and implement in the same environment. The use of advanced metering has shown promising advantages within the South African market and implementation of these systems are ongoing through the help of partnerships between the government and private sector (Cloete et al., 2014; Masia and Erasmus, 2013; Monontsi et al., 2011). Government have acted towards sustainable housing and development. It is deployed to provide housing for those in need (Othman, 2009; Western Cape Government, 2011; Windapo and Cattell, 2013).

Renewable energy plants within South Africa have been rising and more plants have been built. The South African Government confirmed that 27 renewable energy projects will create 61 000 full-time jobs and add R56 billion worth of new investments in the economy over two to three years (South African Government News Agency, 2018).

Transportation is continuously improving the environment with multiple public transport establishments in cities across South Africa and have shown advantages users with low income (Gajjar and Mondol, 2016). Conversely, disadvantages such as theft, robbery and time delays influence daily users and need to be addressed (Yusuf et al., 2017).

Water management, managed by the government in South Africa, is been critically addressed to implement sustainable technology within the Department of Water and Sanitation. It includes mobile water treatment technology that can promote access to clean water to support SDG (Cole et al., 2017; Mwabi et al., 2011; Van Vuuren, 2013; Western Cape Government, 2011).

Table 4.5 outlines various technologies that may improve the agriculture sector of South Africa.

Other technologies show prominent technologies that may affect the South African usage of technology in the mining and extraction departments which reduce the risk of mining and extraction of minerals and natural gasses (UN, 2016*a*).

According to Hipkin (2003), there are three main factors that have to be accounted for when deciding on and managing technology, namely: the skills and level of the personnel in the organisation where the technology is to be implemented, how complex the new technology is to operate and maintain and whether the new technology can be used to its full potential without depending on the technology supplier. The first factor of consideration can be applicable to any situation depending on whether the environment is ready for new technology or not. South Africa is a developing country and has infrastructure to incorporate the best technology on the market. However, some areas of South Africa lack and the needs of the market differ.

Humankind is emerging on a “learning race” against the global environmental and social change (Rockström et al., 2009). The new circumstances will bring internal changes which include new mind-sets and new practices. The overflow of change will provide new professional norms, new institutional incentives, and imaginative ways of rethinking social ecological interactions (Tàbara, 2013).

4.3 Chapter 4: Conclusion

This chapter summarised six different technology categories and discussed each category by outlining the technology, opportunities and potential threats it presents. Technology has great potential to support sustainability, but is accompanied by equally great concerns of impact. There are various types of emerging technologies that could help reach SDGs until 2030. This chapter concludes with potential areas of benefit for the South African environment. The next chapter discusses SD within South Africa and current views on SDGs of South Africa.

Chapter 5

Sustainable Development, Sustainable Development Goals and identifying South Africa's SDG areas of improvement

Sustainable Development (SD) can be seen as a process with the goal of achieving sustainability. These processes include the selection and implementation of a development option without compromising the natural system on which it is based (DEA, 2011).

This chapter explains how South Africa is fostering SD, the current challenges faced and discusses the focusing areas which is currently addressed within South Africa. This chapter also includes subsections that introduce the Sustainable Development Goals (SDGs), current status South Africa finds itself in and identifies areas in which technology innovation can improve current SDG status.

5.1 Fostering Sustainable Development in South Africa

The current strategy and sustainability in South Africa are represented through the National Framework for Sustainable Development (NFSD) and the National Strategy on Sustainable Development (NSSD). These two developments are important for South Africa to meet their international obligations, within the context of the constitution (Western Cape Government, 2011). Figure 5.1 provides an illustration of the hierarchy of planning frameworks government departments at all levels need to respond to (DEA, 2011). The three sectors represented in Figure 5.1 are government, private and civil society.

Government work with the National Committee on Sustainable Development (NCSD), government departments, civil society, and private sectors to ensure that there is positive progress

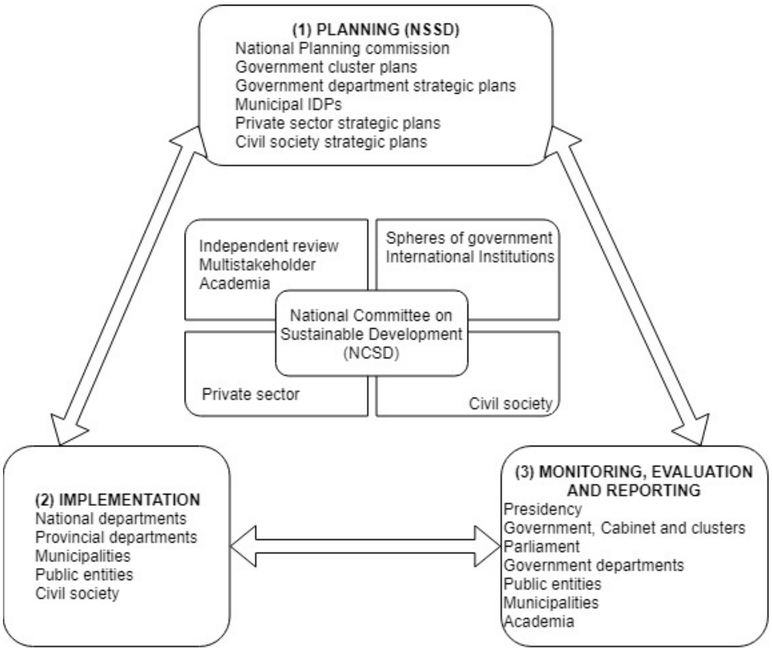

Figure 5.1: Responsibility matrix (Adapted from DEA, (2011)).

regarding planning and implementation of SD throughout all spheres, both nationally and internationally. The focal point is the DEA. Internationally, the Commission on SD participate in international issues related to SD and have to ensure that policy decisions and activities are tailored to support national SD obligations (DEA, 2011).

The private sector, suppliers of societal goods and services, are responsible for identifying SD action plans for their relevant sector, and monitoring and reporting on SD progress to the NCSD. The private sector is also responsible for contributing towards research and development that support SD projects and initiatives in the private sector. The key role player in the South African environment is the civil society who is represented by Non-Governmental Organisations (NGOs), community-based organisations and labour. They identify, design and implement community-based SD projects, participate in research on SD and track performance of government and private sector against SD targets (DEA, 2011). SD is a process that does not providing the community with an end solution. However, it is a process that provides communities with a framework that can be used to empower themselves. They can use what suit them best in their own environment and develop initiatives where these solutions can be included into government frameworks and public policy (Nathan, 2018).

5.1.1 Sustainable Development challenges within South Africa

Challenges exist within South Africa and the rest of the world. However, SD processes are ongoing and prevent a disruptive environment. One of the main challenges faced by technologists is aims that are too narrow. They seldom aim to protect the environment, which can be changed. Technology could be successful in the ecosystem if the intention is towards the system as a whole (Beder, 1994). According to the United Nations (UN) (2016*a*), there are five categories under which each challenge arises, namely: social, technological, economic, environmental and political.

SDGs is a platform that provide strategies and help where needed to overcome challenges that may be faced. Within the environment of South Africa, there are three essential entities, namely: government, private sector and civil society. These strategies are building blocks used by these three entities to strive towards achieving the SDGs. These three entities, collectively, can help reach sustainability within South Africa. They have shown progress in various fields. However, SD is a process that could continue indefinitely if challenges are not addressed.

The three aforementioned entities have made progress through multiple partnerships and contributions. The South African government have made their contributions in terms of the constitutional law of South Africa and are involved in the determination of strategies, direction and regulation of practice. Various challenges remain within the government structure regarding policy tensions, capacity constraints and institutional problems (DEA, 2012).

Through multiple management structures, environmental management has become a diversified profile at policy level and attempts to manage emerging fields of climate change, sustainable design, integrated environmental management and strategic environmental planning in the environmental sector (DEA, 2012). There is more than one SDG promoting the sustainability of human rights and places the responsibility on the governance system to secure and protect the environment in order to provide the civil society with a healthy and clean living environment (DEA, 2012).

Internationally and nationally, food security is impacted through various drivers such as population growth, increasing affluence and urbanisation, availability of arable lands, soil degradation, water resources and climate variability (Von Bormann and Gulati, 2014). To protect remaining natural resources, knowledge and understanding on environmental limitations, restoration of degraded environments, prevention of irreversible losses and prevention of degradation of natural resources is required (Western Cape Government, 2011). To protect and secure food resources, provision of policies and/or frameworks that place sustainability in the middle of land use and management that does not counteract or undermine sustainability are necessary (Western Cape Government, 2011).

The biggest challenges that the world could face in sectors such as manufacturing, construction, and transportation include innovations that must expand rather than reduce the workforce and ensure that more people move out of poverty into the middle class (Colglazier, 2016; UN, 2016*a*).

A major sustainability challenge faced by South African is that currently, the country consists of open, low-density and car-dependent settlements in need of transformation into new, sustainable higher-density, integrated , low-carbon and sustainable settlements. This problem is intensified by problems with residential densities, transport options and can also be linked to demographic, economic and cultural factors (DEA, 2012). A risk faced by South Africans is the ability to modify the environment, through processes such as industrialisation and urbanisation. The risk and challenges move from maximising economic growth and consumption, to a relationship between a healthy economy, society and environment. By building societal values and behaviour for sustainability, one encourages a new way of viewing success (DEA, 2012; Western Cape Government, 2011).

Whether the principles of South African law are good or bad, good governance should be considered as being equally applicable to civil society and the private sector as they are to government. By promoting good and ethical behaviour in sustainable communities and a fairer society requires equitable access to resources, tackling poverty and enabling participative governance (DEA, 2012).

To understand all current and future challenges of SD in South Africa and worldwide, is impossible without a visual model. Figure 5.2 is a visual model based on governments' priorities for Rio+20, with nine dimensions of the environmental ceiling based on the planetary boundaries set out by RockstrÃűm *et al.*, (2009). This visual model conceptualises the notion that there is an "optimal space" towards sustainability. Figure 5.2 presents a visual representation of living under the ecological limits of the planet while operating with the social and economic needs of the planet's human inhabitants (Raworth, 2012; Rockström et al., 2009).

Through partnerships between a group of scientists associated with the Stockholm Resilience Centre, nine planetary boundaries have been identified as follows (DEA, 2012; RockstrÃűm et al, 2009):

i. Climate change;
ii. Biodiversity loss;
iii. Biogeochemistry;
iv. Ocean acidification;
v. Land use;
vi. Freshwater;
vii. Ozone depletion;
viii. Atmospheric aerosols; and
ix. Chemical pollution.

According to the DEA (2012), some of these have already entered the danger zone which may lead to adjustment of the current limits and disruption of biological activities. With the

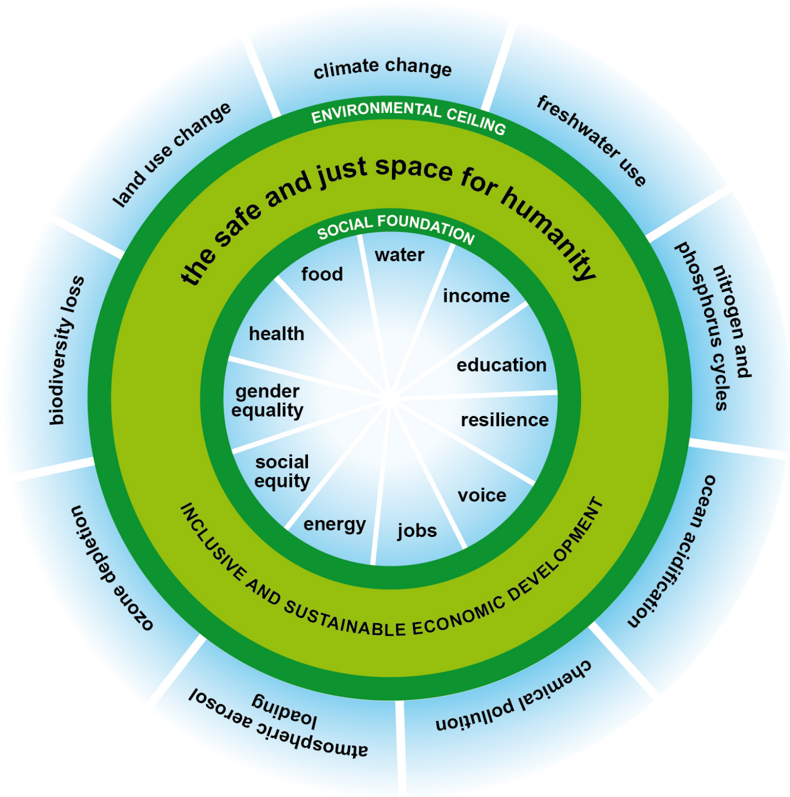

Figure 5.2: A safe and just space for humanity to thrive in: a first illustration (Raworth, 2012).

help of government priorities for the Rio+20 conference, 11 key social priorities of food security, adequate income, improved water and sanitation, health care, education, decent work, modern energy services, resilience to shocks, gender equality, social equity, and having a political voice have been identified (Raworth, 2012).

The overall aim of global economic development is to provide humanity with tools to thrive within the boundaries of SD, whereas society needs to ensure that the 11 social deprivation indicators are fulfilled and responsible management of human activities to prevent exceeding the planetary boundaries is achieved (DEA, 2012; Raworth, 2012).

5.1.2 Sustainable Development areas of focus within South Africa

Global support systems have been put into place to foster SD. The aim of current SDGs is not only to implement these SDGs in most countries, but also to include every country. According to the UN, Global Sustainable Development Report (2016*a*), themes have been identified for optimal leveraging of technology for the SDG.

The first of these four themes includes strengthening national systems of innovation to accelerate technology progress. This theme includes proposals such as:

i. The systematic strengthening of national systems of innovation;
ii. Incremental and radical technology and infrastructure performance improvements;
iii. Removal of barriers in technology deployment and diffusion which include the increase of research and development investments;
iv. Techno-economic policies needed; and
v. Strengthening of literacy in science, technology, and innovation.

The second theme is plans, roadmaps and integrated assessment and includes proposals such as:

i. Increasing the investment in technology;
ii. Sharing of information and advice among countries on policies; and
iii. Partnerships, technology roadmaps and action plans of national and international standing for achieving the SDG individually and together.

The third theme is identified as putting technology at service of inclusion. This proposal includes:

i. Affordable modern technology for everyone;
ii. Inclusive innovation policies to promote equity;
iii. Promote the access and use of technological innovations; and
iv. Explicitly consider informal cultural norms and the nexus to formalise rules when assessing technology needs/gaps.

The last theme is identifying by building institutions that support sustainable technology progress. This theme includes proposals such as:

i. Institutions need to be reformed to re-orient innovation systems towards SD;
ii. Support research and development incentives;
iii. Promote open source innovations and identify new tools; and
iv. Scientific innovations for data collection and analysis to monitor and promote the SDG with big data.

Through these proposals and ongoing support from various partnerships, the process towards sustainability needs to be adapted by each country. By identifying key societal players within South African borders, it may be possible to reach SDGs as set out by the UN through partnerships and the Agenda 2063 (refer to the next section). With the help of the NCSD, the implementation of SD processes can be categorised as decentralised through the strategic plans of all spheres of government, public entities, civil society, organised labour and businesses. Furthermore, the NCSD is responsible for distilling information from reports gathered, verifying the accuracy and validity thereof and producing annual reports to be presented to Parliament and the UN (DEA, 2011).

The NFSD provides an outline of South Africa's national vision for SD and indicates strategic interventions to re-orient South Africa's development path. Here the NSSD builds on the NFSD and provides an overarching implementation strategy and action plan (DEA, 2011) centered on the five priorities identified by the NFSD (Western Cape Government, 2011).

These five priorities have been redefined by the NSSD, in order to identify five strategic interventions required to achieve the nation's vision for SD (DEA, 2012). These interventions includes:

i. Enhancing systems for integrated planning and implementation;
ii. Sustaining our ecosystems and using natural resources efficiently;
iii. Moving towards a green economy;
iv. Building sustainable communities; and
v. Responding effectively to climate change.

5.2 Sustainable Development Goals

Rio+20, a United Nations (UN) conference on SD held in Rio de Janeiro, saw member states launch a process in order to develop the current SDGs and was also the beginning of new partnerships to advance SD in world (UN, 2012).

> "*The SDGs, otherwise known as the Global Goals, are a universal call to action to end poverty, protect the planet and ensure that all people enjoy peace and prosperity*" (UN, 2016*b*)

These are the words from UN who set out these SDGs to improve the lives and future prospects of all humanity. The 17 SDGs include the following in the Agenda 2030 (UN, 2016*b*): no poverty; zero hunger; good health and well-being; quality education; gender equality; clean water and sanitation; affordable and clean energy; decent work and economic growth; industry, innovation and infrastructure; reduced inequalities; sustainable cities and communities; responsible consumption and production; climate action; life below water; life on land; peace, justice and strong institutions; and partnerships for the goals. To achieve these SDGs, partnerships between governments, private sector, civil society and citizens are essential to ensure the planet is left in a better state for future generations. This is represented in Figure 5.3.

While these SDGs are set out for everyone, the African continent have committed to implement the African Union (AU) 2063 Agenda. The 2030 Agenda for SD acknowledges the importance of the AU 2063 Agenda and considers it an integral part of SD (UN, 2016*b*). The 2063 Agenda, which is both a vision and plan to build a prosperous Africa in 50 years, is a strategic framework for the socio-economic transformation of the continent and builds on and

Figure 5.3: SDGs (UN,2016*b*).

seeks to accelerate the implementation of past and existing continental initiatives for growth and SD (AU, 2013).

Agenda 2063 includes seven aspirations as follows (AU, 2013):

i. A prosperous Africa, based on inclusive growth and SD;
ii. An integrated continent, politically united, based on the vision of Africa's renaissance;
iii. An Africa of good governance, democracy, respect for human rights, justice and the rule of law;
iv. A peaceful and secure Africa ;
v. Africa with a strong cultural identity, common heritage, values and ethics;
vi. An Africa whose development is people driven, relying on the potential offered by people, especially its women and youth and caring for children; and
vii. An Africa as a strong, united, resilient and influential global player and partner.

5.2.1 South Africa's current status on the SDGs

The current 17 SDGs set out in the previous section consist of smaller indicators that contribute to the bigger picture. Currently, there are 230 indicators within the 17 SDGs. South Africa is able to measure 156 of the 230 indicators that have agreed standards and methods set out by the UN. Within the 156 measured indicators, data on a number of indicators may not be available at any point in time. South Africa is able to report on a number of SDG indicators, although there are data gaps in specific SDGs (Statistics SA, 2017).

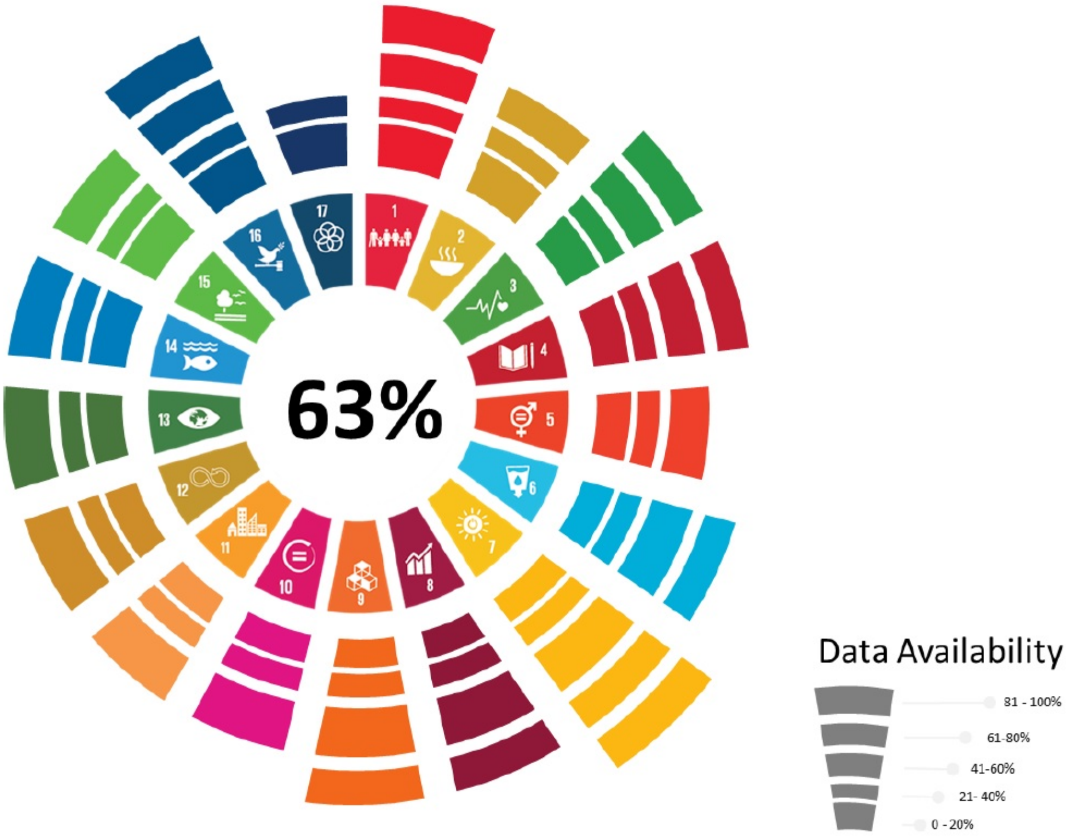

Figure 5.4: Data on SDGs availability within South Africa (Statistics SA, 2017).

Figure 5.4 shows the 17 SDGs and their availability of data. The weakest one is partnerships to achieve the goal, whereas affordable and clean energy emerged at the top. Figure 5.4 shows that South Africa has 63% data availability within the indicators of the SDGs, confirming that there are data gaps in numerous SDGs. This section explains South Africa's current position on achieving the different goals with the available data (Statistics SA, 2015).

Goal 1: No Poverty

South Africa is "*fundamentally geared towards the elimination of poverty and the reduction of inequality through job creation programs and creating conducive conditions for entrepreneurship in order for the majority to be in employment*" (p. 24) (Statistics SA, 2017). The biggest victims of poverty in South Africa and those who require special focus are individuals living in rural areas, with little or no education, women, children and black Africans (Kimemia and Van Niekerk, 2017).

Taking the international poverty line into consideration, South Africa has adopted the Lower-bound Poverty Line (R647 per person per month in 2015) as the primary benchmark for monitoring poverty within the country. South Africa's poverty rate (below Lower-bound Poverty Line) has decreased from 51,0% in 2006 to 40,0% in 2015 (Statistics SA, 2017; The World Bank, 2018).

Goal 2: Zero Hunger

Food security can be described in many forms. However, it is more than just the availability of food. Food security consists of issues such as affordability, nutrition/food utilisation and stability of food supply into the future (UN, 2017). South Africa developed the National Food and Nutrition Security Plan which includes six objectives that are supported by the three sectors (government departments, civil society and private sector), with partnerships to achieve the SDGs.

South Africa has an experienced agricultural sector with advanced research in and the preservation of a variety of plant and animal genetic resources within gene banks (AU, 2017). The research in the agricultural department plays a critical role in fostering sustainability in competitiveness and profitability to enable South Africa to compete in the world that rapidly transforms into a knowledge and network economy (Statistics SA, 2017).

Goal 3: Good Health and Well-being

According to Statistics SA (2015), an average of 0,9% of income is spent on health expenditure while this number rises to 1,04% in rural settlements. These percentages mainly consist of medical services (44%) and pharmaceutical products (38,71%).

South Africa's health system requires strengthening by improving governance and eliminating infrastructure backlogs. The health system can be improved through promoting health, providing universal health coverage, ensuring no backlogs in the system and providing enough resources to help those in need. The National Department of Health can improve the health system by improving facility planning, financial management, providing effective health care information system and setting norms and standards of quality service in the health care department (SchÃűnfeldt et al., 2018; Statistics SA, 2017).

Goal 4: Quality Education

South Africa has shown tremendous progress towards transformation along five internationally acknowledged dimensions ofs access, redress, equity, quality and efficiency. While the department has shown progress in these dimensions, the department also provided 10% (88% to 98%) increase in schools with access to electricity from 2012 to 2016, while schools with access to internet steadily increased from 12,9% in 2012 to 19,7% in 2016. With all these improvements in education, there was an upward trend in completion rates in grades 7, 9 and 12, with only a 50,1% pass rate in grade 12. School drop-outs have remained high, but decreased from 2013 (36,9%) to 2015 (35,0%) respectively (Statistics SA, 2015; Statistics SA, 2017).

Goal 5: Gender Equality

South Africa consists of great inequality and attention must be directed towards addressing gender gaps and strengthening empowerment of women to provide South African citizens with a country in which everyone is equal (Statistics SA, 2017).

Goal 6: Clean Water and Sanitation

According to Statistics SA (2017), South Africa is the 30th driest country globally, suggesting that greater attention to the management and use of water in South Africa is needed (Sershen et al., 2016). The Water and Sanitation Department must ensure strengthening of existing water monitoring networks and that riparian countries meet SDGs targets to assist in improvements in South Africa(Nhapi and Gijzen, 2005).

South Africa's governance and legal framework provides the platform "*for the development of a National Water Resources Strategy to set out the objectives, plans, guidelines and procedures relating to the protection, use, development, conservation, management and control of water resources in a manner that takes into account basic human needs of present and future generations*" (p. 94)(Statistics SA, 2017). Through this new strategy it is possible for South Africa's water and sanitation policy and legislative regime to be aligned to the Agenda 2030 for SD.

Goal 7: Affordable and Clean Energy

"*Addressing the lack of clean, reliable and affordable energy for billions of people in remote places and not near a reliable power grid is one of the world's most critical development challenges*" (p. 104)(Statistics SA, 2017).

South Africa has a vast electricity network that provides electricity to neighbouring countries. Despite this, South Africa remains one of the most unequal societies in the world (Azimoh et al., 2016; Statistics SA, 2017). According to Statistics SA (2017), electricity contributes to the reduction of poverty and bridging the inequality gap in South Africa. The country has managed to connect 207 436 new households to the electricity grid in the 2016/2017 financial year. However, there remain communities that are mostly not easily accessible without access to electricity.

Goal 8: Decent Work and Economic Growth

South Africa has a high rate of unemployment and has shown an increase from 2014 (24,9%) to 2016 (26,5%), respectively. Highest rates of unemployment are among women, demonstrating inequality (Porter, 2014; Statistics SA, 2017).

Goal 9: Industry, Innovation and Infrastructure

While South Africa is a developing country, it is important to excel in SDGs such as this one. This SDG has three aspects of SD, namely: infrastructure, industrialisation and innovation. Each one plays a crucial part in reaching most or all of the SDGs. The first aspect, namely infrastructure, provides the back bone of any society or enterprise by supplying basic physical systems and structures. The next aspect, industrialisation, drives economic growth, creates jobs and reduces poverty. The third aspect, innovation, supports advances of technological capabilities within the industrial sectors and leads to development of new skills (Statistics SA, 2017).

Through technological advancements, it is possible to find solutions to both economic (new jobs) and environmental challenges (clean energy). Innovation is a well-established environment and attempts toward new technology are well under way in various sectors and different technology categories (UN, 2016*a*). With the help of this SDG and the innovation environment, possibilities are endless and could help South Africa to raise employment rates through economic growth and improvement of the quality of education, skills development and innovation (Anadon et al., 2016).

Goal 10: Reduced Inequality

Inequality exists in many forms within South Africa and is mostly evident in the distribution of resources and income (The World Bank, 2018). By addressing other SDGs (quality of health care, education, and other critical services) and providing improved living standards, could lead to a reduction in inequality within South Africa. However, progress in reducing inequality has been slow (Statistics SA, 2017).

Goal 11: Sustainable Cities and Communities

South Africa has a complex history and complicated infrastructure in urban areas. Thus, turning urban areas into sustainable cities is a major challenge in this country. An estimated 63% of South Africans live in urban areas. A total of 25 municipalities consist of over 55% of the population and contribute to over 70% of South Africa's GDP which provides new job opportunities. These major municipalities grew over 20% between 2001 and 2011 (Statistics SA, 2017). By changing one attribute, disruption within urban areas takes place, leading to many more disruptions.

However, with good planning and partnerships, sustainable cities can be achieved within South Africa (Kramers et al., 2014).

Goal 12: Responsible Consumption and Production

South Africa has a large economy but an even larger emission of carbon dioxide. This is mainly due to the large dependency on carbon-based fuels. The world has turned towards greener technology and energy generations. Thus, South Africa is most likely to face challenges to reduce these emissions. However, with the current water shortages, it has become evident that everything has either a positive or negative impact on the economy, the environment and social development (Schiederig et al., 2012).

According to the UN (2016*b*), SDG 12 can be achieved if the creation of goods and services use processes and systems that are non-polluting; conserving of energy and natural resources; economically viable; safe and healthful for workers, communities, and consumers; and socially and creatively rewarding for all working people. Statistics SA (2017) states the following: "*achieving sustainable consumption and production patterns secures efficiency and productivity gains, ensuring that human activities remain within the carrying capacity of the planet*" (p. 150).

Goal 13: Climate Action

Climate change is the consequence of irresponsible consumption, production and other related actions of humankind. Thus, multiple sectors (water, agriculture and commercial forestry, health, biodiversity and ecosystems, and human settlements) have been identified to consider climate change impacts (Geels, 2012). South Africa has made changes in the business sector such as implementation of adaptation technologies. Medium-term adaptation strategies are piloted and further research is being conducted to conserve the world's ecosystem and biodiversity assets (Statistics SA, 2017).

Goal 14: Life Below Water

Given the extensive marine life of South Africa which many local communities depend on, it has become an environment that sustainable consumption and protection. There are about 29 000 subsistence fishers and a few large-scale fisheries that employ approximately 27 000 people. These jobs are all at risk if marine life is not protected and sustainably managed. However, South Africa is protecting about 848 km coastline and 4 172 square kilometres of ocean. These coastal areas, marine life and more are crucial for people to survive. Employment opportunities are at risk when looking at consumption from a SD perspective (Branch *et al.*, 2002; Statistics SA, 2017).

Goal 15: Life on Land

Life on land in South Africa has endless beauty, diversity and culture. Through these rich biodiversity assets, the country has the opportunity to support its development path and provide opportunities such as investments into the ecosystems, with multiple social, environmental and economic benefits (Blanchard et al., 2011). Within the South African environment, irresponsible consumption puts pressure on the biodiversity and more often than not, it is the poverty stricken communities that suffer from the pressure. Therefore, long-term planning to promote biodiversity and the conservation is critical (Statistics SA, 2017).

Goal 16: Peace, Justice and Strong Institutions

Fighting crime in South Africa is one of the major struggles faced by the government, which aims to accomplish the SDG of better life for all and ensure that all people in the country remain, and feel safe. In order to achieve this SDG, the government requires coordinated activity across various departments, private sectors and community bodies (Stiglitz, 1999). Achieving less or no poverty, better education and higher levels of employment can help towards achieving this SDG and addressing inequalities in the country (Statistics SA, 2017).

Goal 17: Partnerships to achieve the Goal

South Africa has various bodies that work together to keep the country in a good state. The tax revenue system is one of the cornerstones of the South African democracy. It is critical that government invest into the tax system to ensure smooth operation and fostering of sustainability. Statistics SA (2017) stated that ICT will underpin the development of a dynamic and connected South African information society that is more prosperous (Mbuyisa and Leonard, 2015). The Cabinet approved a framework that includes the use of ICT and introduced a policy to ensure universal access to broadband for all South Africans by 2020. With the right partnerships and vision, South Africa can become a prosperous country with endless opportunities.

5.3 South African areas that can be improved through technological advancements

In order for technology to not only make a difference, but a difference in the right direction in world, it will have to incorporate sustainable strategies that fit into each situation. A resilient infrastructure which is reliable and consistent with good quality is required.

Identifying technologies to foster SD within South Africa without any infrastructure on the life cycle of the technology could be disastrous. Therefore, specifying certain infrastructure, processes and innovation platforms and proceeding further with the steps set out, could lead to achieving most or all of the current SDG. In society today, nothing goes unseen, untouched or unspoken. As such, connecting the SDGs and working them as a unit ensures that none are left behind.

Partnerships, planning, infrastructure and innovation can all be seen as critical points and can either work or not. SDG 17 not only represents partnerships within the SDGs, but also in the environment as a whole. Through successful management of SDG 8, 9 and 17, South Africa can provide multiple business sectors with platforms to work from. These platforms can ensure that processes are being met according to standards and regulations.

Statistics SA (2017) stated that ICT could become South Africa's cornerstone of information sharing platform. The technology ICT was evident in multiple business sectors described in Section 3.4, which demonstrates that South Africa is currently on the right path to success. However, the lack of management has placed the implementation structures and infrastructures of these platforms in a bad light (Mbuyisa and Leonard, 2015). ICT and the management of ICT can ensure that these three SDGs are well implemented and managed within South Africa and beyond.

SDG 3, good health and well-being, is most likely the costly expenditure in the everyday lives of South Africans. Technologies that make it possible to among others, edit genomes and customize DNA sequences in the category of biotechnology can re-engineer how humans live from day zero until their death. However, these technologies can become very expensive. It entails costly medical treatments on patients, which are not sustainable. There is a need for South Africa to invest in efficient, effective and quality health care units that can be reached by any citizen in the country. Thus, it is necessary to invest in sustainable technology that can be re-used and delivers quality outputs within the industry.

Technologies such as gene editing and customized DNA sequencing could be beneficial for South Africans given that many infants are born with defects that affect the whole life of the individual and their family. Other technologies such as IoT may benefit the health sector by providing a platform to reach those in need and who do not have the time or money to travel to health care facilities.

Effective education in South Africa is fundamental to ensuring that citizens become knowledgeable and are able to secure jobs. Education is a crucial learning opportunity and the lack of quality education leaves the country with a weak work force comprised of individuals that lack knowledge. Multiple technologies, such as digital technology, could assist the South African education environment and provide devices for learners to get used to technology and the extent to which these technologies can be utilised. Green technologies could benefit the education sector by supplying sufficient, sustainable and reliable energy sources ensuring the availability of knowledgeable sources learners may need.

Clean water and sanitation are necessities mostly taken for granted in South Africa. However, recent water shortages in the country has reinforced the fact that it is crucial to manage South Africa's water sources and infrastructure to provide clean water and sanitation to all people within the country. Technology plays a big role in reaching this SDG within South Africa, through the improvements on generating clean water and the application of technology for decentralised water and wastewater management. Nano-technologies can help South Africa move towards sustainability within the department of water and sanitation through the right frameworks, implementation and management of the technology. By applying green technology, it may become easier to supply water to people that are difficult to reach with infrastructure. Green technology (such as mobile water treatment technology) may provide a stepping stone towards sustainability.

The more technology driven a country becomes, the more energy it needs to keep the technology running. Green technologies play a critical role for any country in order to provide more affordable and clean energy to its citizens. South Africa has a wide variety of consumers and a more complex system than other countries. As such, management of such systems and the implementation approach is important. An advanced metering system is one of the newer green technologies in South Africa and has been proven to work (Monontsi et al., 2011). Green technologies such as off-grid electricity systems and mini-grids based on intermittent renewable energy with storage enables society to provide electricity to those who do not have any. Other sources of clean energy, such as solar and wind have risen tremendously and continue to grow since the government announced that it will provide capital in this regard (South African Government News Agency, 2018).

Considering the rise in citizens within South Africa, the need for sustainable cities and communities is growing. Sustainable cities can be defined as a city designed with consideration of the environmental impact it has and the minimisation of required inputs (such as energy, water and food) and outputs (waste, heat, air and water pollution). By focusing on other SDGs, sustainable cities can be created to some extent through clean energy and water, effective education, quality health provision, responsible consumption and strong institutions of justice. However, the planning, infrastructure and implementation is a lengthy process and can take time to reach its full potential.

South Africa has significant infrastructure for all sectors and struggles to produce with responsible consumption. SDG 12 makes provision for achieving more with less and ensuring that human activities remain within the capacity the planet can offer. Technologies that can improve and/or contribute towards this SDG include neuro-technologies and green technologies. These can assist the sectors of manufacturing in producing the same amount with less to no pollution and inputs. This SDG improves when the technology is non-polluting, conserves natural sources and energy, economically beneficial, safe, healthy and rewarding to all members of society (Statistics SA, 2017).

SDG 16 has a number of underlying factors, including the lack of education and work opportunities. Technology within this department is crucial in certain aspects of the environment. This environment includes crime where human identification cannot work as efficiently and effectively as technology, such as murders, robberies and much more. These digital technologies will equip the police department of South Africa with more insight into certain aspects of the crime industry and can help shift society towards freedom without fear of crime. IoT and 5G mobile phones can enable easier identification and locating of people, whereas neurotechnologies such as AI can track suspicious content and report this when identified (Kariuki, 2009). Restrictions in the crime environment include the regulations and rights of individuals.

Certain SDGs of the UN are easier to achieve than others. However, certain aspects are fixed and these SDGs set out by the UN are aimed at improving countries and striving for SDGs that promote a better and more prosperous future. In order for South Africa to transition from the current state of unsustainability towards sustainability, the necessary frameworks and approaches need to be put in place. By identifying and creating the necessary frameworks and approaches, South Africa can easily reach more SDGs and achieve a more prosperous future.

5.4 Chapter 5: Conclusion

Through the help of all mankind in the world, it is possible to reach sustainability. The current SDGs set out by the UN are stepping stones to provide platforms and frameworks for countries to strive towards a better tomorrow. This could be achieved through tackling the main challenges of the SDGs, identifying problems that can be eliminated, providing support to one another and changing the dynamics of how things are done. This chapter reflected on the current state of South Africa in terms of the current SDGs. However, due to a lack of data, limited conclusion can be drawn. Research within South Africa remains a big hurdle in certain areas. Affordable and clean energy is a specific SDG that has come a long way. Probably with the best enhancements in the field of generating and providing energy within South Africa. Therefore, data availability in this field is high. In conclusion, it is evident that by improving one SDG, other SDGs can be achieved easier. By identifying the right technologies, the current state of South Africa could be uplifted and improved.

Chapter 6

Existing frameworks, approaches and models

This chapter discusses existing frameworks, approaches and models. The advantages and disadvantages of the approaches are also listed, to provide a platform for the next chapter. This chapter includes the following transition frameworks, approaches and models: Multi-Level Perspective, Strategic Niche Management, Transition Management, Innovation System, and Evolutionary Systems. However, these approaches only address a limited set of dimensions and don't capture the multi-dimensional environment of Socio-Technical (ST) transition towards Sustainable Development (SD) (Van Den Bergh et al., 2011). As outlined in the literature, the Multi-Level Perspective is a common framework to work from and aids in explaining concepts.

One of the major concerns within developing countries is that of technology adoption and how people react to the new proposed technologies within their environment. Towards the end of this chapter, technology adoption models and approaches are discussed in order to help these transitions succeed. The successful transition will be determined whether or not the new technologies are adopted.

The chapter concludes with recommendations for designing a new framework or expanding an existing framework. Finally, an analysis will be performed to establish whether the design requirements are met by the existing frameworks, approaches and models.

The existing literature on frameworks, approaches and models can provide useful insights on new approaches designed for developing countries. The literature outlines how to understand, implement and manage technologies toward sustainable ST and the transition that forms part of this process. It is evident from the literature that the frameworks, approaches and models mostly fit developed countries and their transitions, while multiple developing countries struggle to find a perfect fit (Lachman, 2013). There is a need for literature (the applicability of existing approaches has been proven to work from developed approaches), to provide developing countries and citizens with frameworks, approaches and models that can help them strive for sustainability (Tigabu et al., 2015).

The complexity of systems made up of governments, businesses, legislation and economic interest, means it is seldom tough enough to foster technological change for ecological sustainability. Figure 6.1 depicts that placing too much emphasis on technological factors without considering all other factors can place constraints on the shaping and implementing of technologies (Beder, 1994). Research has shown that when taken into consideration, the usage behaviours of technology were directly related to the needs of the end user. According to Porter & Donthu (2006), if an incentive was received by the user, it was likely that they would overlook the perceived barriers and adopt the proposed technology. Users doesn't normally like to change things that are working, however, Venkatesh (1999) found that users motivated by the natural way (pleasure and inherent satisfaction derived from a specific activity) were more likely to accept the technology, than any other motivation strategy.

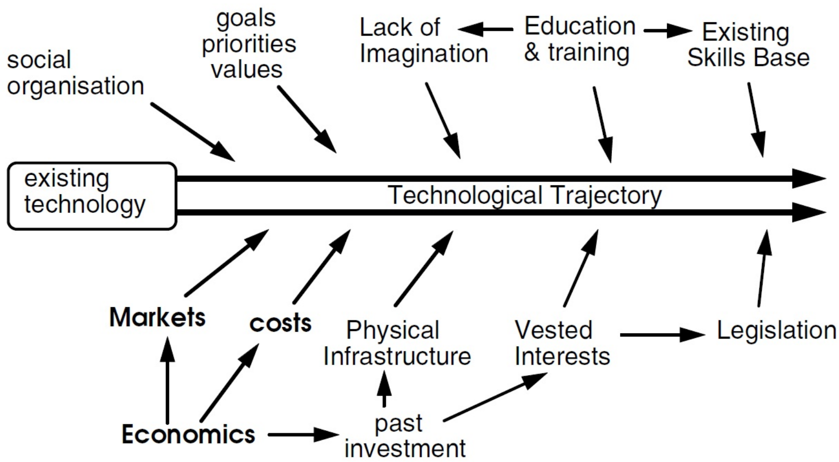

Figure 6.1: Factors that constrain the direction of a technological trajectory (Beder, 1994).

The literature was consulted to investigate the most notable approaches to study ST transitions and technology adoption. Moreover, literature was used as a starting point for developing a new approach on SD transitions. Multiple frameworks, approaches and models are discussed below, as well as their processes and breakdowns. Finally, strengths and weaknesses are identified. In order to tailor the approach or framework towards technology in a ST transition, frameworks, approaches and models can be incorporated due to their nature that deals more with technologies. These models include, amongst others, social construct of technology, technology future studies, constructive technology assessment and technology adoption. Extensive knowledge and understanding are necessary for large-scale transitions to take place. Consequently, a new ST system requires rigorous frameworks, which include multiple approaches and take interactions between society and technology into consideration.

6.1 Multi-Level Perspective (MLP)

A MLP is an approach that conceptualises a pattern of long-term change and centres on ST regimes, where the MLP consists of various elements, phases and levels. MLPs are continuous, as multiple technologies constantly compete in multiple levels (niche/micro, regime/meso, landscape/macro) and in multiple phases that evolve over time. These technologies create various networks that undergo transformations over time, which result in reconfiguration taking place, technologies being substituted and the levels de-aligning and re-aligning (Geels, 2002; Rip and Kemp, 1998; Van Den Bergh et al., 2011).

6.1.1 Analytical levels of the MLP

According to Rip & Kemp (1998), the assumption of a MLP is that due to multiple developments at the three analytical levels, the transition process is non-linear. These levels refer to the different alignments, which formed within the ST system, for increased stability through a nested hierarchy (Refer to Figure 6.2) (Geels, 2012).

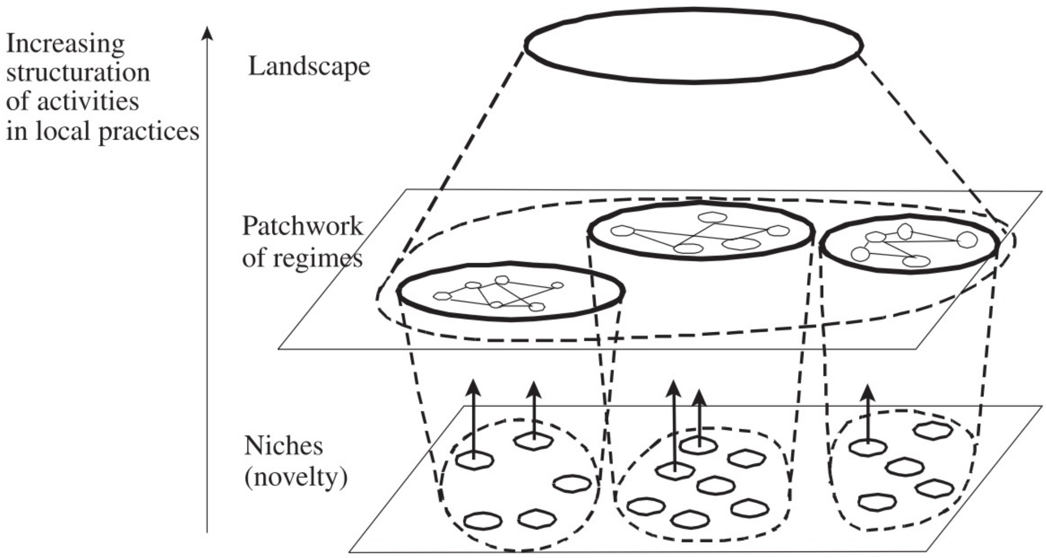

Figure 6.2: Multiple levels as a nested hierarchy (Geels, 2002).

Landscape level

This level is the wider context and has significant influences over the regime and niche levels. However, the other levels have little to no effect on the landscape level (Lachman, 2013). The landscape level represents the greatest degree of structuralism, meaning that the level is beyond the control of individual actors (Geels, 2012).

Regime level

This level can be described as a patchwork of regimes that must compete with one another. According to Raven & Verbong (2009), there are four types of interactions between the regimes, namely competition, symbiosis, spill-over and integration. Within the regimes, three interlinked elements exist: development of a network of actors and social groups, a set of formal and informal rules that maintain consistency and reproduction of the ST system, and the material and technical elements (Geels, 2004). When regimes find themselves stable, and the landscape is favourable, regimes create stronger alignment within the system and thereby create a linked in system (Lachman, 2013).

Niche level

Niches can be described as spaces in which innovation takes place. These spaces tend to be more flexible and less bound by rules (Berkhout et al., 2004). Niches begin with high hopes of eventually being used in regimes, however, niches tend to be short lived. Niches are crucial for transitions as they provide the seeds for systematic change (Geels, 2004). According to past literature on niche-innovation (Hoogma et al., 2004; Rip and Kemp, 1998), three social processes have been identified within niches:

i. Learning processes on various dimensions;
ii. Articulation of expectations or visions; and
iii. Building of social networks and enrolment of more actors.

Niches often include experimental or demonstration projects, which allow niche actors to learn about innovation in real-life situations (Geels, 2004). According to Geels (2004), niches gain momentum if visions and expectations become more precise, the configuration more stable, and social networks become bigger.

6.1.2 Pathways of technological transitions

According to Geels & Schot (2007), MLP scholars have identified five pathways or patterns which define a transition:

i. **Reproduction process (P0)**: During this process there is no landscape pressure and the regime remains stable and will reproduce itself;
ii. **Transformation path (P1)**: There is moderate landscape pressure when niches have not been fully developed, the process triggers regimes to react by adjusting their development paths and innovation activities;

iii. **Technological substitution (P2)**: The significant landscape pressure combined with well-developed niches leads to dismissed regimes, replaced with niches (Geels, 2005);

iv. **Reconfiguration pathway (P3)**: New innovations are adopted within the regime to solve local problems that were generated through niches and trigger adjustments within the basic architecture of the regime; and

v. **De-alignment and re-alignment path (P4)**: Landscape changes can be described as large, divergent and sudden and increase the pressure on regimes. Problems occur in the regimes, causing destabilisation and de-alignment. During this process, niches (new or old, sufficient or insufficient) compete to become dominant in the regime, forming the core for the re-alignment of a new regime (Grin et al., 2010).

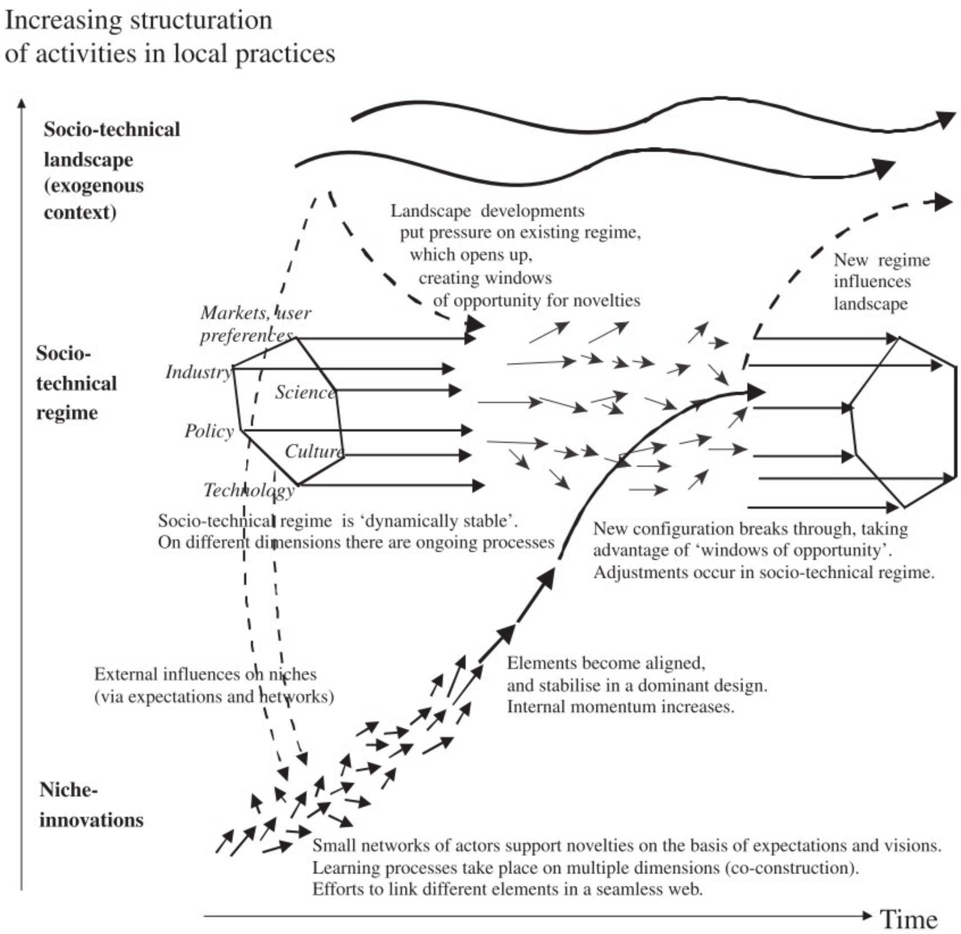

Figure 6.3: Multi-level perspective on transitions (Geels, 2004).

Figure 6.3 provides a representation of the MLP and illustrates how the three levels interact dynamically in a ST transition (Geels, 2002, 2004; Geels and Schot, 2007).

6.1.3 Advantages and disadvantages of the MLP

With the use of the MLP, a conceptual tool with advantages such as scope and generalisability, a user can expect to get a bird's eye view of the transition. This view can help to search for patterns, causes and impacts of different events during transitions (Geels, 2011). Policy makers use this powerful tool to guide transitions in an efficient and effective manner by placing focus on both niches and regimes (Geels, 2012).

A major disadvantage of the current MLP is that it uses metaphors and imprecise concepts, creating danger of obscurity and the ability to categorise events too easily (due to vague boundaries). The MLP is a complex system that contributes toward the criticism this system, as it becomes difficult for the conception of computer models (Geels, 2011; Smith et al., 2010). According to Geels (2011), there are seven critiques within the MLP system and not all of them can be entirely resolved. These seven issues include lack of agency, operationalisation of regimes, bias towards bottom-up change models, epistemology and explanatory style, methodology, socio-technical landscape as residual category, and flat ontologies versus hierarchical levels. Despite these criticisms, the MLP has gained interest within the research environment, helping to unravel these criticisms (Geels, 2012).

6.2 Strategic Niche Management (SNM)

SNM can be described as a tool that supports the societal introduction of radical sustainable innovations. Figure 7.11 depicts the early SNM work of a bottom-up approach. It illustrates where novelties emerge in technological niches, conquer market niches and eventually replace and transform the regime (Schot and Geels, 2008). According to Lachman (2013), the SNM attempts to tackle multiple barriers in order to implement sustainable technologies. These barriers include technological factors, government policy and regulatory framework, cultural and psychological factors, demand factors, production factors, infrastructure and maintenance factors, and undesirable societal and environmental effects.

Evidence has shown that SNM can effectively analyse and explain historical transitions and emerging innovations. SNM scholars have identified three interrelated processes influencing the success of an innovation introduced into society (Hoogma et al., 2004; Lachman, 2013; Mourik and Raven, 2006; Schot and Geels, 2008). These processes include articulation of expectations and visions, building of social networks, and learning processes at multiple dimensions (specifications, preferences, meanings, networks, policies and effects). It is clear that both internal and external factors play a crucial role. Research has shown a correlation between the design of experiments and technological and market niche development outcomes (Schot and Geels, 2008). The SNM

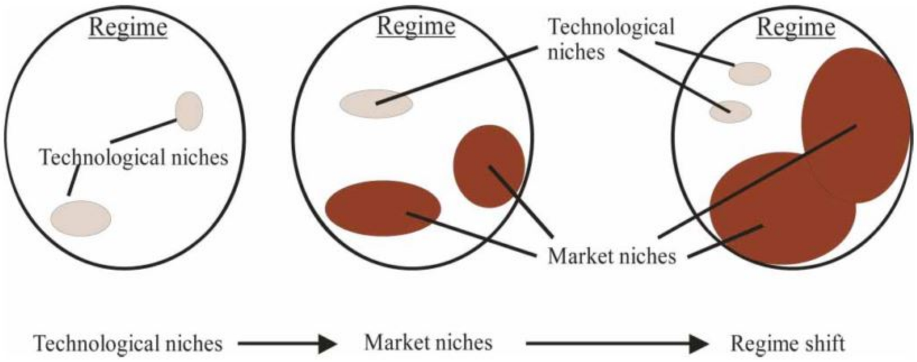

Figure 6.4: From niche dynamics to regimes shift (Schot and Geels, 2008).

suggests that without any help of broader forces or processes, the niche innovation rarely results in a regime transformation.

6.2.1 Advantages and disadvantages of SNM

A criticism of SNM on a broad spectrum is that it fails to provide detailed and practical guidelines for project and niche builders. Several current case studies are based on historical cases and only reflect the actual practice. Therefore, SNM hasn't been put into practice to support or facilitate new experiments (Mourik and Raven, 2006).

An advantages of SNM is that it aims to help those under conditions of considerable uncertainty, with respect to technological specifications and user context. As seen in Figure 7.11, technologies differ and the market is not yet defined as the environment where SNM excels (Schot and Geels, 2008). SNM is more of a design organising project, with potentially radical and sustainable technologies in its early development phase (Mourik and Raven, 2006).

6.3 Transition Management (TM)

Transition Management (TM) is best described as "a reflexive and participative governance concept that attempts to manage transformative change (i.e., influence the speed and direction of change) towards SD by combining long-term thinking with short term action (thus complementing conventional policy) through a process of searching, experimenting and learning" by Lachman (2013). The TM concept has gained traction through key aspects of learning-by-doing and doing-by-learning, including and involving stakeholders constantly, continuous reflection on all levels, and bringing system innovation alongside system improvements (Lachman, 2013; Loorbach, 2007).

6.3.1 Execution of TM

TM is executed on three levels and follows a cyclical path, executing continuous monitoring, evaluation and adjusting on the following levels (Loorbach, 2010; Loorbach and Rotmans, 2006; Loorbach et al., 2008):

i. **Strategic level**: A transition arena, a small network of various frontrunners, develops vision, goal formulation, roadmap, milestones, etc;
ii. **Tactical level**: Implementing a transition agenda towards the desired goal with the consent of regimes, by aligning them with the long-term goal; and
iii. **Operational level**: Experiments are used, rather than chasing "silver bullets", to stimulate learning and thereby guide variation and selection.

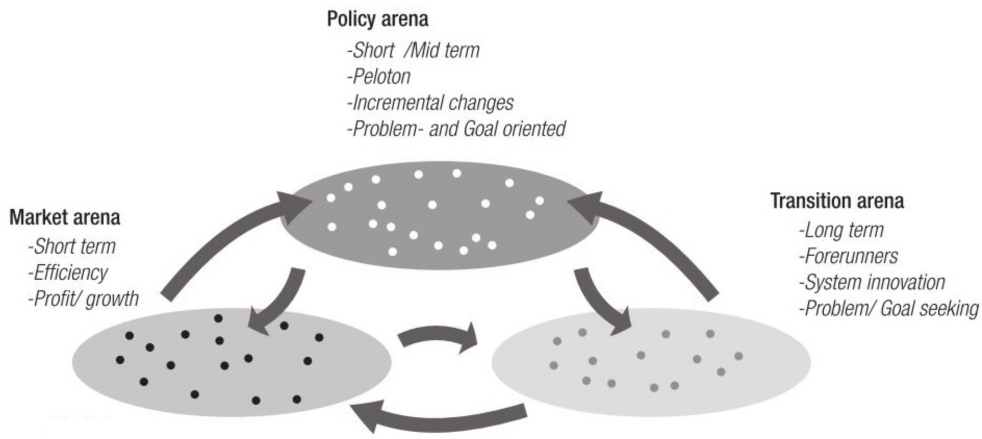

Figure 6.5: Transition arena as alternative circuit enabling SD (Rotmans, 2005).

The TM described in Figure 6.5 proposes a new environment between government and market, allowing innovative long-term reflection, and social learning and collective goal and strategy formulation.

6.3.2 TM criticisms and advantages

TM has been criticised on different levels and approaches within the processes. TM has been identified as difficult to apply in practice and current TM literature focuses more on management of niche-regimes, rather than transition (Lachman, 2013). One of the major criticisms of TM is that TM scholars can assume that transitioning is a managerial task, thereby neglecting the fact that other influences exist in other forms, both inside and outside the TM framework (Shove and Walker, 2007, 2008). Another criticism is that the TM gives little attention to the actors on niche levels, evident from the lack of tools, practices, models, etc. in order to make it in the regime level (Lachman, 2013).

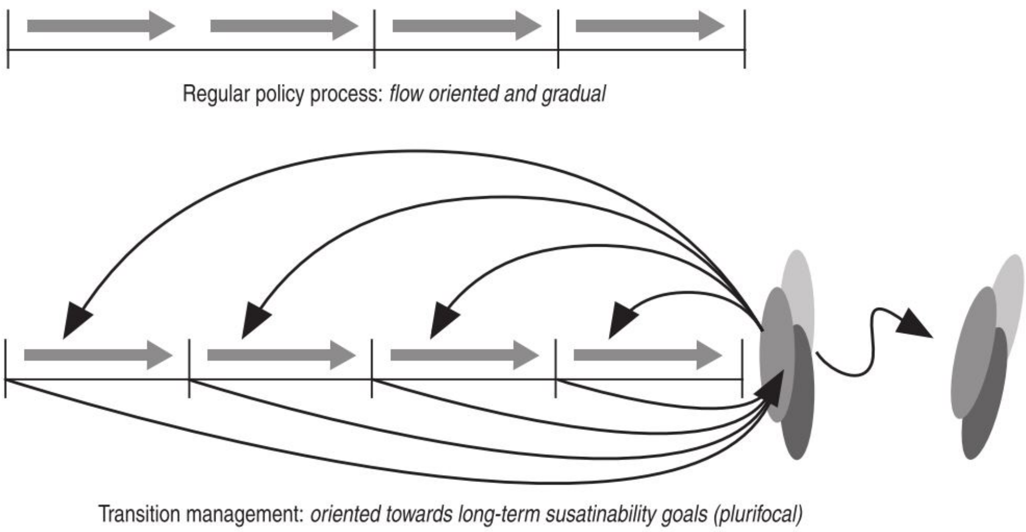

Figure 6.6: Regular policy versus TM process (Loorbach, 2007).

Some advantages of TM is that it uses transition experiments, focusses on frontrunners and envisions sustainable futures. TM systematically evaluates progress of the transition, which makes it possible for TM to adapt to changes in the environment and process (Van Den Bergh et al., 2011). As seen in Figure 6.6, the regular policy process is linear, in which the TM process continues feedback forwards and backwards (Loorbach, 2007).

6.4 Innovation Systems

The Innovation System was introduced back in the mid-1980's to guide "free-market capitalism". However, shortcomings emerged. Innovation System can be defined as the combination of all structures (institutional and economic) that effect the direction and speed of technological change in society (Van Den Bergh et al., 2011). The concept of Innovation System, which covers sectors beyond technical change, is a combination of theories (evolutionary and institutional) and emphasises the co-evolutionary character of change processes (Hekkert et al., 2007; Van Den Bergh et al., 2011). According to Freeman (1995) and Jacobsson & Bergek (2011) there are a number of variations of the Innovation System - such as the National Innovation System, Sectoral Innovation System, Technological Innovation System and Regional Innovation System.

The Innovation System is an interdependent approach, which states that technological change can be seen as a combination of collective and individual actions (Freeman and Perez, 2000). Therefore, the Innovation System contributes to the breakdown of systems into different components, aiding in discovering those that do not achieve their desired outcomes and consequently, obstruct the development of the entire system (Jacobsson and Bergek, 2011). The

Innovation System attracts policy makers because it pinpoints bottlenecks in transition processes by being capable of identifying weak links within the sub-systems (Lachman, 2013).

6.4.1 Criticism of Innovation System

According to Smith *et al.* (2010) and van den Bergh *et al.* (2011), the Innovation System has weaknesses that include difficulties in making new technologies marketable, problems related to the mobilisation of resources, insufficient knowledge development and diffusion, and influences on the direction of search. The Innovation System has been criticised (Geels, 2006; Hekkert et al., 2007) because the approach tends to marginalise cultural and demand side aspects. The approach disregards forces when new technologies attempt to take over, and supports large actors and neglects smaller ones (Lachman, 2013). One of the major criticisms of the Innovation System is that it focusses more on the functioning of the system than system change. As a result, the approach creates solutions for weaknesses, rather than for system change (Geels, 2006, 2011).

6.5 Evolutionary systems

Evolutionary theory identifies three outcomes (variation, selection, and differential replication) as processes of change, where changes in the system result from progressive adoptions on multiple levels. The key elements and mechanisms of the system are diversity, variety generation and selection, with additional features such as rationality, path dependence and lock-in, group selection and co-evolutionary dynamics (Safarzyńska et al., 2012).

The system evolves through different modelling approaches, which differ on whether time is discrete or continuous, strategies are finite or infinite, and whether they involve deterministic or stochastic processes. The three modelling techniques include evolutionary game theory, evolutionary computation, and agent-based modelling and these techniques all attribute different characteristics and outcomes. The evolutionary game theory is normally used when a single strategy is given with no innovation mechanisms required. Evolutionary computation is suitable for addressing adaptive learning, search and optimisation mechanisms. The final modelling, an agent-based approach, allows non-linear interactions among a large number of heterogeneous agents to be modelled beyond the scope of any other technique (Safarzyńska et al., 2012).

6.6 Technology Adoption theories, models and approaches

6.6.1 Innovation Diffusion Theory

This theory consists of movement through stages of engagement with technology such as knowledge stage, persuasion stage, decision stage, implementation stage and confirmation stage (Rogers, 2003). The primary engagement between technology and user occurs at stage two, the persuasion stage. This stage consists of five innovation attributes/predictors, namely complexity, compatibility, trial ability, and observability (Rogers, 2003).

6.6.2 Technology Acceptance Model

The Technology Acceptance Model (TAM) is one of the most widely used and empirically tested models in the technology acceptance field (Davis, 1989). According to Davis (1989), there are two perspectives (usefulness, and ease of use) that would lead to the use of a particular technology. Thereafter, if intention levels are high, it may lead to actual use of the particular technology (Cloete et al., 2014). The TAM has been critiqued for being too simplistic (Gefen and Straub, 1997; Legris et al., 2003). Venkatesh & Davis (2000) modified the TAM framework to form the TAM2 by expanding the external variables to include perceived instrumental factors, social influences and the user's past experiences (Refer to Figure 6.7).

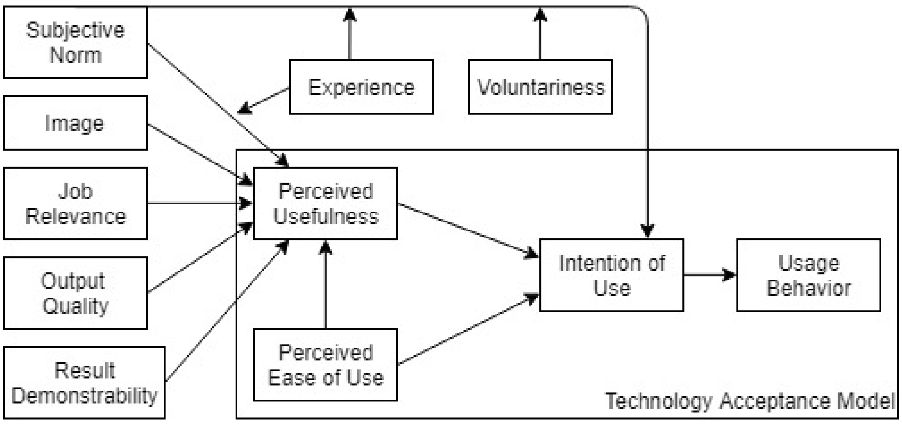

Figure 6.7: Extension of the Technology Acceptance Model (Adapted from Venkatesh and Davis, (2000)).

However, both of the TAM approaches have received criticism for assuming that the adoption process is influenced by features or qualities of the technology (Cloete et al., 2014). Green (2001) has attributed social circumstances to also having a significant impact on the adoption process. Musa (2006) has extended the framework of the TAM2 and addressed the problem by introducing a new perception of the socio-economic environment with concepts of values, accessibility, and exposure to target technology (Refer to Figure 6.8). The adoption of new technology is facilitated by positive factors (economic activity, good health systems, good governance, etc.) and inhibited by negative factors (poverty, corruption, minimal access to basic resources, etc.) (Musa, 2006). The revised TAM, seen in Figure 6.8, suggests a two-way interaction between socio-economy and access to technology. This interaction shows that a lack of access to technology would drive negative factors and vice versa.

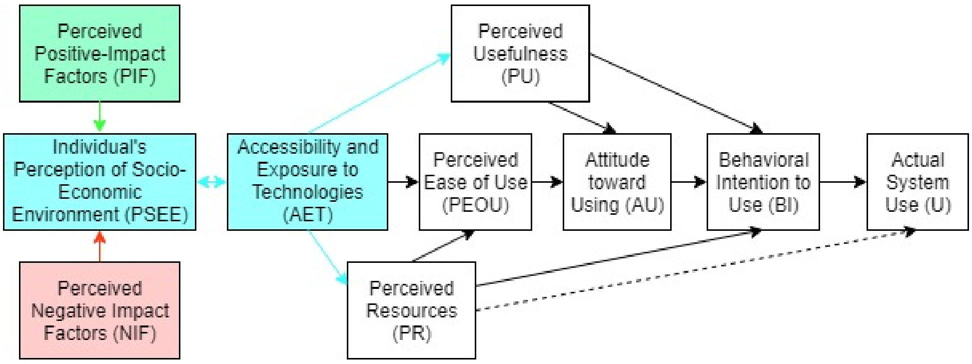

Figure 6.8: The revised TAM: Accounting for accessibility of technology (Adapted from Musa, (2006)).

6.6.3 Unified Theory of Acceptance and Use of Technology

The Unified Theory of Acceptance and Use of Technology (UTAUT) is a combination of various models modified by Venkatesh *et al.* (2003). The UTAUT consists of four determinants, namely performance expectancy, effort expectancy, social influence, and facilitating conditions. These determinants predict international behaviour and lead to prediction of the actual behaviour (Cloete et al., 2014). The strength of the relationship, determinants and behavioural intention are influenced by four moderating factors (gender, age, experience, and voluntariness), included in the theory in the form of a hypothesis model (Cloete et al., 2014).

6.6.4 Affective and Persuasive Design

The affective design refers to the relationship between the end user and the qualities of the technology (Cloete et al., 2014). Khalid (2006) developed a model in which the first step is to match the end user's perceived needs, with the appropriate technology. This is followed by the next step in which the product is evaluated against their needs, and the final step of the model is to adopt or reject the technology. This model aims to understand what the user needs and then designing the relevant technology based on these needs.

Regarding the persuasive design, this method makes use of technologies that are designed to change the behaviours, motivations and attitudes of the end user (Fogg, 2002). The persuasive design aims for technological designs that influence behaviour change irrespective of the end user's needs (Cloete et al., 2014). According to Fogg (2002), the persuasive design should be used according to ethical procedures that match motivation, abilities and triggers and emphasises that the approach should not be abused. Fogg (2009) argued that technology is more persuasive when one or more of the motivators (sensation, anticipation, and social cohesion) is high. Simplicity is central to persuasion and identifies six elements: time, money, physical and mental effort, social deviance, and non-routine behaviour (Fogg, 2002). Moreover, Fogg (2002) identifies three types of triggers which influence the behaviour, namely facilitators (behave easier), sparks (motivates a behaviour), and signals (indicates or reminds a person of the behaviour).

6.7 Conceptual framework outline

Given the review of literature, this section outlines the envisaged conceptual framework that provides guidance for industries and policy makers when implementing technology with the aim of contributing towards SDGs and SD. This conceptual framework should aim to provide decision support to industries that are in the process of implementing new technologies and/or moving towards more sustainable practices within the respective industry and country. This conceptual framework thus considers three entities namely SDGs, industry and technology. The conceptual framework provides an industry perspective in order to establish support mechanisms for the current SDGs and how technology can support the SDGs.

The framework focuses on an industry, and this serves as initial input. The first step in the framework is to align industry contributions to the SDGs and establish how the industry can contribute towards the SDGs. The second step is to assess the technologies that are applicable to a specific industry and identify how these technologies could support the view and contributions towards the identified SDGs and contribute towards the SDGs. The last step in the framework involves connecting technology with industry through assessing how the transition and adoption of the technology(ies) can be aligned in a way that SD is promoted and contributions to SDGs take place. The outcome of this conceptual framework aims to provide guidance for selection, implementation and usage of technologies to support industries to contribute towards SDGs.

In the following section, the design requirements that will guide the development of the proposed framework, as discussed above, is presented.

6.7.1 Design requirements

The first requirement of the conceptual framework is that it should be a generic model that can be used in any industry aiming to implement or adopt new technology(ies) for transitioning towards SD and concurring the current SDGs.

The conceptual framework, with its broad context matter, should ideally be user friendly and easy to implement in industry. However, given the level of complexity when dealing with sustainability, SDGs and the role of industry and technology when aiming to contribute towards sustainability, one should caution against over simplification. Therefore, an adequate level of complexity will be aimed for. The conceptual framework should facilitate industry in identifying the SDGs they aim to employ and/or incorporate and/or explain how their operations could positively contribute towards the SDGs.

The conceptual framework should aim to provide a systematic process that connects entities (industry, technology and SDGs) with each other through the various actions, operations and technologies an industry aims to implement. These 'connections' are considered first and foremost from an industry perspective.

The nature of this conceptual framework should be suitable in for choosing technology for specific actions and operations within an industry. This guidance should includes the identification of SDGs that could be contributed towards through the implementation of the technology within the concerned industry.

Lastly, the orientation of the framework should by undeniably towards sustainability to guide the user towards sustainability and sustainable technology, along with providing the user with useful information on how to successfully and purposefully contribute towards SD. The conceptual framework therefore should aim to guide an industry to consider technologies that supports sustainability within the industry, and by implication also on a larger scale. It should be noted that the level of analysis is however at industry-level.

Overall, the conceptual framework should aim to guide the user in developing a report outlining the benefits of the technology within the industry and identifying which SDGs can be positively impacted. The framework, however, does not measure sustainability, nor does it identify specific technologies.

6.7.2 Comparing existing frameworks, approaches and models with design requirements

Taken into consideration the above mentioned requirements and characteristics, and given existing frameworks, approaches and models that aim to provide guidance when transitioning towards SD with the help of technology, Table 6.1 show which requirements are met by the various existing frameworks, approaches and models. These existing frameworks, approaches and models has been selected due to their notability within the transitioning environment (Lachman, 2013; Markard et al., 2012). From Table 6.1, it is evident that there is no specific framework, approach or model that currently aligns with the stated requirements.

Table 6.1: Existing frameworks, approaches and models meeting the new design requirements

	Existing frameworks, approaches and models								
New Design Requirement	Multi-Level Perspective	Strategic Niche Management	Transition Management	Innovation Systems	Evolutionary Systems	Innovation Diffusion Theory	Technology Acceptance Model	UTAUT	Affective and Persuasive Design
Generic model	x	x	x		x		x	x	
User friendly						x	x		
Identify industry contribution towards SDGs									
Connects entities (industry, technology and SDGs)				x	x				
Guidance for choosing technology		x			x	x	x	x	x
Recognise and improve sustainability									x

The existing frameworks, approaches and models have various characteristics as discussed in section 6.1 - 6.6. Even though no single framework is identified as a framework that satisfied the identified requirements to ultimately reach the stated aim and objectives of such a framework, Table 6.2 categorises most of these important and most relevant characteristics of the various existing frameworks, approaches and models that could be used to develop the proposed conceptual framework.

It is evident that sustainable transitions should be goal-oriented, such as addressing persistent environmental problems. The ideal transition does not necessarily offer technology that is beneficial to users and is likely to have a lower price/performance dimension than established technologies (Geels, 2011). Making the transition towards sustainability wouldn't be possible without economic framework changes such as taxes and subsidies, amongst other in order to convince society, private and government sectors to change towards SDs (Cloete et al., 2014; Kant and Lehrer, 2005; Schrader and Thøgersen, 2011). Geels (2011) implies that sustainable transitions are influenced by interactions between technology, policy/power/politics, economics/business/markets, and culture, discourse, and public opinion.

Table 6.2: Important transition and technology adoption characteristics

Transition-related variables	Bird eye view (MLP) (Geels, 2011)
	Big scope and generalisability (MLP)
	Thinking/learning in multi-domains, with multi-actors, at multi-levels (TM/SNM) (Schot and Geels, 2008)
	Continues feedback into the system (TM) (Loorbach, 2007)
	Pinpoints bottlenecks in transitions (Innovation Systems) (Lachman, 2013)
	System innovation concurrent to system improvements (TM/Innovation Systems) (Edquist, 1999)
	Clear view of expectations and visions (SNM) (Schot and Geels, 2008)
	Long-term thinking (TM) (Lachman, 2013)
	Gradual change (TM)
	Identifies different pathways for technological transitions (MLP)
Technology-related variables	Identify the performance expectancy (TAM/UTAUT) (Davis, 1989)
	Easily repeatable and good trail abilities (Innovation Diffusion Theory) (Rogers, 2003)
	Considering the technology's reliability (Musa, 2006)
	Good technical support and guidance (Musa, 2006)
Individual/psychological variables	User's biographical factors (age/gender/culture/language ability) (Cloete et al., 2014)
	User and society needs (Khalid, 2006)
	Persuasive technology and motivation (Fogg, 2002)
Social/community variables	Legal framework including punishments and incentives for compliance (Cloete et al., 2014)
	Guidance and alignment for policy makers (MLP/Innovation Systems) (Geels, 2012; van Lente et al., 2012)
	Building social networks (SNM) (Schot and Geels, 2008)
	Financial incentives (relative cost, rebates, discounts, etc.) (Fogg, 2002; Porter and Donthu, 2006)
	Socio-political pressure

6.8 Chapter 6: Conclusion

This chapter identifies the most applicable frameworks, approaches and models and explains how they function. In addition, their advantages and disadvantages are discussed. This chapter further identifies the necessary transition adoption theories and discusses how they are applicable. The chapter concludes with design requirements of the proposed conceptual framework (developed in the next chapter), describes these requirements, compares the existing frameworks, approaches and models with the design requirements and lastly, identifies a list of important characteristics to consider when developing the conceptual framework.

Chapter 7

Industry and technology alignment with SDGs framework

This chapter first provides an overview of the theory pertaining to the relationship between the SDGs, industries ad technology. The chapter then provides the discussion of the development of the proposed framework and describes the refined framework. After the refined framework presented, it is described how it can be used further upon implementation in practice. This chapter entails phases 5 to 7 of Jabareen's Conceptual Framework Analysis method, thus the framework (as discussed in section 7.2 and 7.3) is constructed from the results of part 1. The last section of this chapter, section 7.4 depicts phase 7 of the Conceptual Framework Analysis.

As highlighted in the stated framework requirements (section 6.1), the framework developed here focusses on the linkage and alignment of and between industry, SDGs and technologies. The objective of the framework is to connect industry and technology through a common denominator; the SDGs - aiming to contribute towards identifying and enabling an environment where industry and technology coherently aim toward the same sustainability goals and objectives. The purpose of this conceptual framework is to provide industries with guidance when choosing and implementing technologies in striving towards SD and/or positively impacting SDGs.

The last section of this chapter presents the first phase of the validation process, based on qualitative data gathered from Subject Matter Experts (SMEs). The validation method is based on validation questions presented to SMEs subsequent to an in-depth explanation and review of the developed framework. In addition, the last section of this chapter also discusses the results of the validation questionnaire and provides the refinements, adaptions and changes incorporated into the framework based on the feedback from the SMEs during the validation process. It should be noted that the refined and updated framework are presented in this chapter, the preliminary framework can be seen in the validation document that was used in the validation workshops and distributed to SMEs (refer to Appendix A).

7.1 SDGs, industries and technology

The purpose of the proposed conceptual framework is to create a link between industry and technology by connecting or aligning both to the SDGs. The framework is used to connect and align the SDGs between industry and technology in order to achieve similar goals. Figure 7.1 shows the connections that are needed in order to build the conceptual framework.

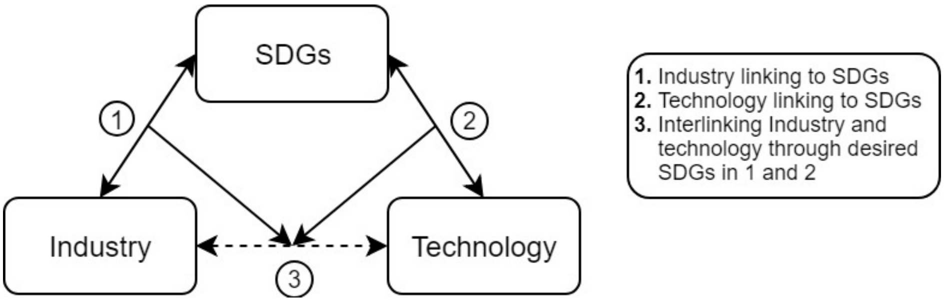

Figure 7.1: Refined Conceptual Framework.

7.1.1 Focus on SDGs

In today's world, nothing goes unseen, untouched or unspoken. Therefore, connecting the SDGs and working them as a unit ensures that none are left behind. South Africa consists of various bodies (within government, private and society entities) which are constantly improving multi-dimensional planning (refer to Figure 7.2) (Leigh and Blakely, 2013; Stimson et al., 2006) to strive towards sustainability. A key challenge of achieving the SDGs is that sectoral planning dominates the cross-sectoral planning within the development planning (Musango et al., 2015). Some of the major aspects for improvement of sustainability are stakeholder participation, coordination and commitment in order to achieve SDGs through successful cross-sectoral integration (Thabrew et al., 2009).

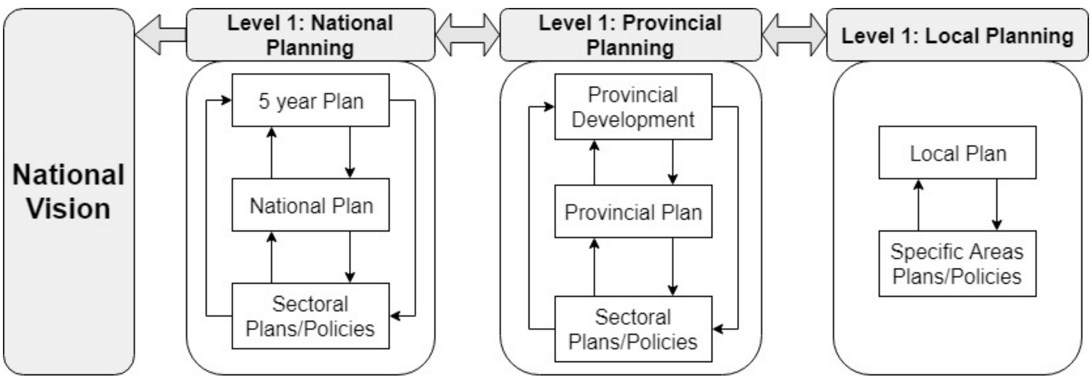

Figure 7.2: Schematic representation of plans in various levels of government (Adapted from Musango et al., (2015)).

In light of this, it is necessary that national strategies are evidently used and developed within the local communities for SD.

According to Musango (2015), most developing countries are fostering solutions for socio-economic issues (e.g. poverty, inequalities) while most developed countries seek to transition towards a green economy that would result in an increase in employment and improve development of the economy. According to Maria *et al.* (2015) it is evident that strategies differ between developed and developing countries. Therefore, focussing on certain SDGs as a country could improve much more than just the SDGs aimed for.

The Green Economy concept (a concept that supports SD and SDGs) can be described as an approach to improve economic development and control environmental deterioration (Bina, 2013). The Green Economy concept has gained attention recently and many countries, regions and cities are adopting the concept (Maria et al., 2015) in order to strive towards sustainability.

7.1.2 The link between industry and SDGs

When trying to reach the SDGs, resources are required (AU, 2013); this is evident and noted by the South African government that has made contributions towards SD within the constitutional law of South Africa (Western Cape Government, 2011). Through various bodies, the government is involved in the determination of strategies, direction and regulation of industrial practices to contribute towards sustainability (DEA, 2012).

Within the South African environment, the sustainability strategy is represented through three bodies, NFSD, NSSD and the NCSD. It is the task of these three bodies to ensure South Africa meets international sustainability obligations, within the context of the constitution (Western Cape Government, 2011). The NFSD is involved in South Africa's development path by providing an outline of national vision for SD and strategic interventions. The NSSD provides an overarching implementation strategy and action plan that builds on the approach of the NFSD (DEA, 2011). According to the DEA (2011) industries are responsible for identifying, planning, supporting and monitoring their SD actions and reporting on progress and performance to the NCSD. The NFSD have identified five priorities, which were redefined by the NSSD in order to identify strategic interventions. These priorities include (DEA, 2012):

i. Enhancing systems for integrated planning and implementation;
ii. Using natural resources efficiently and protecting the ecosystem;
iii. Move towards a green economy;
iv. Building sustainable communities; and
v. Responding effectively to climate change.

Currently, Agenda 2030 (as developed by the UN) consists of 17 SDGs set out to be achieved by 2030, with the AU 2063 Agenda playing an integral part (UN, 2016*b*). To support the current SDGs, the AU 2063 Agenda and NFSD strategic interventions, the proposed framework can be used to promote the transition towards a green economy. According to the Western Cape Government (2013) there are five identified drivers for transitioning towards a green economy namely:

i. Smart living and working;
ii. Smart mobility;
iii. Smart ecosystem;
iv. Smart agri-production; and
v. Smart enterprise.

These drivers consist of switching the current situation towards a "smart" way of living and doing things. The proposed framework provide, to a certain degree, sufficient guidance for sustainability when applying technology to enhance industry. The guidance the proposed framework provides clarified as sufficient in such a way that the user is guided towards aligning industry with technology, in order to strive towards similar SDGs.

7.1.3 The link between technology and SDGs

When identifying technologies to foster SD within South Africa, factors that influences the decision maker are endless and requires a relevant criteria when assessing these technologies for implementation. Such as specifying certain infrastructures, processes and innovation platforms could lead to sustainability and/or achieving and/or contributing towards the SDGs.

According to Nathan (2018) there are technologies available to make development sustainable, but the challenge remains in deploying them in the right way. Challenges arise in various forms and according to the UN (2016*a*) there five categories of challenges, namely: social, technological, economical, environmental, and political. Nonetheless, the Global Sustainable Development report (2016*a*) identifies four themes for optimal leveraging of technology for the SDG:

i. Strengthening national systems of innovation to accelerate technology progress;
ii. Plan accordingly, design roadmaps and integrate assessments;
iii. Incorporating technology for inclusiveness; and
iv. Build institutions that support sustainable technology progress.

In order to create an environment conducive to the adoption of technology and sustainable development, transitions need to be made (Aldemir and Gülcan, 2004; Clements-Croome, 2011). Despite various tools on how technology can be managed, available from both national and international organisations, challenges and failures still exist within developing countries (Hipkin and Bennett, 2003). The existing infrastructure and platforms (promoting SD) provided by the unions and departments are sufficient tools to promote the community with the economic instruments, legislative measure and consumer pressure. These platforms and unions provide such services and products promoting technological change for SD within the current environment (Beder, 1994).

7.1.4 Linking the industry to technology

Technology within any industry plays an undisputed role in modern societies, is a key driver for innovation and sustainable business growth (Dolata, 2013). To put technology into perspective, it possesses both positive and negative factors towards the sustainable modern-day production and consumption patterns (Smith and Stirling, 2008). Technology can be of good use when in need of good service, maximum value and lowest cost within any industry (Schot and Geels, 2008). This said, the focus of how technology is applied to an industry changes. These changes include the application of technology to the supply chain, for instance, technology was used to simplify and improving the manufacturing plant where as the new application of technology is towards making the entire supply chain cross multiple industries linked to contribute towards SD (Linton et al., 2007).

Industries and organisations are repeatedly affected by technological advancements, driving industries towards a flexible and customised change model to fit the social network of the industry and/or organisation into which technology is being introduced (Appelbaum, 1997). Feenburg (1999) supports this statement and suggest that technology and society co-evolve mutually and influence each other. In order for technological innovation to influence society, their relationship and connection has to be understood (Johnson and Wetmore, 2009).

The influence industries and technologies have on each other forces both technology and industries to evolve over time. These changes to the ST system (both society and technology) requires a broad perspective of the ST system as a whole. This barrier can be overcome by creating feedback loops that connect activities in different stages of the innovation process and technology life-cycle (Bergek et al., 2008). This feedback provides important information regarding other stages of the innovation cycle to include the past, present and future stages of the process in order to ensure an innovation that is applicable (Anadon et al., 2016).

New innovative technologies often fall short of implementation due to a number of factors, including not being able to disrupt incumbent technologies. Incumbent technologies often occur when feedback loops are created to continuously refine and adapt the current technology(ies) in use (Arthur, 2007). Locked-in technology(ies) also occur when powerful factors influence the decision-making process and bias the institutions governing innovation systems to meet their preferences (Anadon et al., 2016).

A infrastructure that is resilient, reliable and consistent is needed to take on the new innovations of technology and adapt to the fast pace changes.

7.2 The refined framework

This section provides an succinct account of the refined framework.

Figure 7.3 depicts the refined framework. Figure 7.3 illustrates how all the SDGs can be focused upon structuring infrastructure around the concurring SDGs. The different circles in Figure 7.3 represents different focus levels, with the inner circle the key focal point.

According to Le Blanc (2015) SDGs can be seen as a network. This network links SDGs among each other to target multiple SDGs. This framework (refer to Figure 7.3) uses a dedicated SDG, SDG 17, that cuts cross the means of implementation for the whole set of SDGs (Le Blanc, 2015).

This framework consist of four circles (shown in Figure 7.3) and could be focussed upon from the inside towards the outside. The four circles can be seen as a network, where the two inner circles contains the cornerstone SDGs of the framework, direct SDGs in the third circle and the indirect SDGs in the fourth circle. The construction of the circle is described below.

7.2.1 The cornerstone SDGs

Within this framework, partnerships, planning, infrastructure, innovation, decent work and economic growth can all be seen as critical points. SDG 17 not only represents partnerships within the SDGs, but also in the environment as a whole. When actions within any environment are sufficient enough in SDG 8, 9 and 17, there aren't any catastrophic failures in sight within the environment itself. These SDGs provide stability within the framework and infrastructure of the environment.

SDGs 8 and 9 can be seen as a working team. This is of importance because when identifying specific problem areas or opportunities within the environment, these SDGs create the necessary infrastructures to surpass the problem. By focusing solely on SDG 9, one could easily lose sight of the end goal of achieving sustainability.

Statistics SA (2017) stated that ICT can become South Africa's cornerstone of information sharing platforms. Creating spaces in developing environments for technology is concerning and therefore implementation structures and infrastructures of the environment need to be sound (Mbuyisa and Leonard, 2015). Through successful management of SDGs 8, 9 and 17, South Africa can provide multiple business sectors with a platform to work from and ensure that the right steps according to standards and regulations are being taken. SDG 8, 9 and 17 can be seen as foundational building blocks to provide other SDGs with a platform achieve most or all of the SDGs.

Within the environment of South Africa, SDG 8 (decent work and economic growth) goes hand-in-hand with SDG goal 9 (industry, innovation and infrastructure). These two goals identify problem areas or opportunities within the environment and create the platforms and infrastructures needed to surpass the affected areas.

Circle 1

The inner circle of circle 1, consists of goal 17. This is at the core of this framework and is solely based on the concept of partnerships. Partnerships for goals and partnerships on its own holds considerable value when aiming to connect and align the supply chain or industries, making it easier for industries to cooperate. An industry who makes use of this framework needs to focus on key partnerships (Goal 17). Through key partnerships, it becomes easier to reach the desired outcome and improve more SDGs.

This circle is a key part of this framework. In this refined framework, the partnerships this circle and goal refers to is including multiple partnership levels. The partnerships the circle refers to is any agreement between two or more parties in or outside the specified industry. These partnerships that can be specified in the framework can include the various levels of the industry, however the level of report structure has to be kept in mind. The user has to ensure that the usage of the framework maintain a specific detail review of the industry and technology.

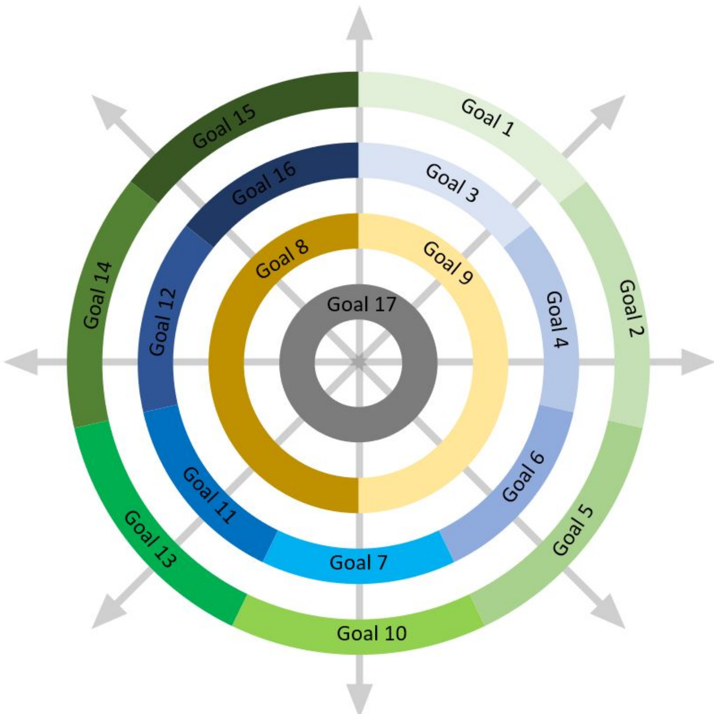

Figure 7.3: Industry and technology alignment with SDGs framework

Circle 2

Circle 2 represents goal 8 and 9. The objective of goal 8 is to support the industry to ensure the stability of the working environment and economic growth. Whereas the objective of goal 9 is to ensure that industries keep striving for innovative ideas within their respective industry and to ensure the maintaining of the infrastructure within the entire industry.

When using this framework, SDG 8 and 9 has to be action specific. Thus, when completing circle 2, one has to ensure that the information is relevant to the specific problem and changes the industry identified.

Through the help of the inner two circles, the planning, infrastructure and implementation to facilitate the outer circles improves. These two inner circles represent the cornerstone of the process and are essential for any industry to foster these goals. By doing the right thing through these goals, all the other goals become easier to reach.

7.2.2 Direct SDGs

The direct SDGs of this framework is evident in circle 3 and consists of all SDGs that can directly be influenced by actions. The framework specify that SDG 3, 4, 6, 7, 11, 12 and 16 form part of the direct SDGs in this framework. Industries that acts towards SD could identify which SDGs in this circle are the ones on which they have an impact, and that they can (ideally) improve and/or contribute towards. The key idea is that by improving and/or contributing towards the SDGs represented in this circle will in turn enable industries to indirectly influence circle 4.

7.2.3 Indirect SDGs

The outer circle, circle 4, represents the indirect SDGs in this framework. These SDGs could be improved and eventually accomplished when SDGs in the inner circles are improved and/or have been fully achieved. Circle 4 represents the SDGs that can be focused on when the other SDGs gain momentum and show improvements. The SDGs presented in circle 4, seen in Figure 7.3, can be improved through other improvements in SDGs.

To put the use of these circles into perspective, for example, by improving the education system and creating opportunities, more people could potentially gain access to working opportunities making it possible to support their families in need. This process would ultimately end up improving SDG 1. By focusing on circle 1 and 2 in Figure 7.3, it could improve the chances of achieving circle 3 and 4 without specifically focusing on circle 3 and 4, highlighting the interrelatedness of the SDGs.

7.2.4 Framework summary

From Figure 7.3, it is evident that most of the inner circles have potential to change the current status of South Africa towards sustainability with the help of technology innovation and implementation. Some SDGs are linked to technology innovation, as explained in 4.2, that could help current and future situations.

This framework exclude various factors influencing the decision maker, which implies that this framework would not have an affect on the decision maker if used solely to choose a specific technology. The environment of choosing technology to implement have various challenges, such as government structure, policy tensions, capacity constrains and institutional problems (DEA, 2012). According to Intarakumnerd *et al.* (2002), governments play a pivotal role in the success of developing countries through numerous possibilities of positive linkages with other actors.

Transitioning towards SD does not necessarily mean beneficial technologies for production and/or services. Making transitions successful towards SD implies a wide variety of factors, entities and participants, such as interactions between technology, policy/power/politics, economics/business/markets, and culture/discourse/public opinion (Geels, 2011).

The circles, from inside to outside, in Figure 7.3 can be seen as building blocks to achieve SDGs in coherent, and arguably more efficient and effective ways. The next section describes the framework as a process, divided into three different steps, with the input described before step 1 and the output at the end of step 3. In the following section the framework is explained in further detail on how it can be used.

7.3 The usage of the Industry and technology alignment with SDGs framework

The refined framework, *Industry and technology alignment with SDGs framework* (refer to Figure 7.3), is translated into a process (seen in Figure 7.4). The usage of this framework requires input and consists of 3 steps that is based on qualitative data. Steps 1 and 2 are independent of each other, where step 3 continues on the outcomes of steps 1 and 2. The outcome of the framework is derived from step 3 where industry and technology are aligned in their mutually desired SDGs.

This section consists of 3 steps, with steps 1 and 2 is independent from each other (refer to Figure 7.3). Step 3 compiles the results from the previous steps and provides an output.

7.3.1 The input

In order for any industry to make use of the framework, it is necessary that the industry has the inputs required to start with the framework. The following inputs are required:

i. Identified industry type;

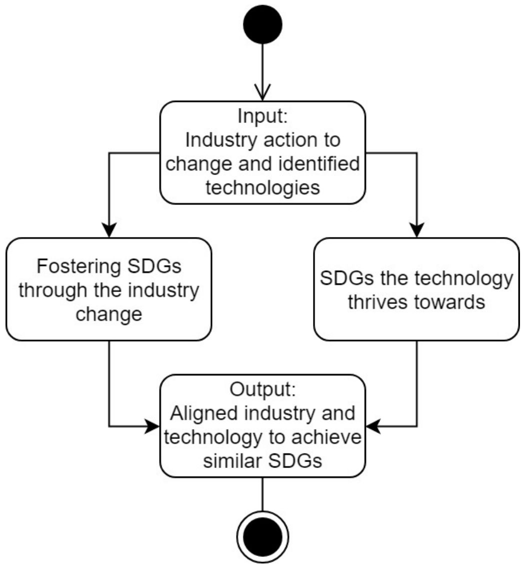

Figure 7.4: Industry and technology alignment with SDGs framework process

ii. Activity in which department within the industry wishing to change; and
iii. Technologies aiming to implement.

The identified industry type includes the user, which should be the user of the framework. The second input refers to the operation the industry aims to change. The last input includes the technologies identified by the industry which they aim to implement for future use in that specific activity in the industry. The industry movement towards being more sustainable includes the replacement of or implementation of technology within the industry. As such, this tool will be applicable to industries needing to replace or incorporate technology in order to strive towards the SDGs and ultimately achieve sustainability.

The framework can be used in various situations and has the ability to function with various levels of input data, producing detailed reports based on the quality of the input. These features enable this tool to be generic and user friendly. The information put into the framework can guide industry in terms of what to focus on, what challenges might be faced and lastly what SDGs it may improve. The framework can also be analysed further, improved or adapted to align with the current state of the industry or technology.

7.3.2 Step 1: Linking of the industry to SDGs

Within this framework, the first step would be to set out the SDGs aimed to be improved or contributed towards through the action of the industry. By applying Figure 7.4 to circle 1, 2, 3 and 4 of Figure 7.3 and providing a process flow, Table 7.1, 7.2, 7.3 and 7.4 have been developed respectively. As seen from Table 7.1 and 7.2, the industry has to "identify the actors within the industry”. This question is followed by “actions between the actors to affect the SDG”, “how this action will affect the SDG” and lastly the “challenges” identified.

Table 7.1: Industry assessment on SDGs in circle 1

Cornerstone SDGs	**Goal 17**: Partnerships to achieve goal
Actors contributing towards this SDG	
Actions between the actors to affect the SDG	
Challenges	

Table 7.2: Industry assessment on SDGs in circle 2

Cornerstone SDGs	**Goal 8**: Decent work and economic growth	**Goal 9**: Industry, innovation and infrastructure
Action of industry to improve SDG		
How will this action affect the SDG		
Challenges		

After Table 7.1 and 7.2 have been completed, the industry needs to identify which SDGs in circle 3 it will aim to improve and/or contribute towards. In Table 7.3 (referring to circle 3), the industry has to identify wherever it can or cannot contribute towards and/or improve the SDGs. This is followed by providing information on “how the industry can improve the SDG” or provide a reason “why not”. Table 7.3 further investigates “how the SDG will improve” and what the possible “challenges” it might face will entail when trying to improve or contribute towards the SDG.

Table 7.4 represents the fourth and last circle. These SDGs are indirectly affected by the previous circles. Once again, the industry will need to identify wherever they can or cannot improve and/or contribute towards the SDGs. If the specific SDG can be improved, the industry has to provide the predecessor(s) (SDGs in circle 3 that will contribute towards SDG in circle 4) in order to create a flow chart (referring to Figure 7.5). The last number of questions include “how the industry can improve the SDG” or provide a reason “why not”.

Table 7.4 concludes by investigating “how the SDG will improve” and what the possible “challenges” it might face when trying to improve or contribute towards the SDG may be.

Table 7.3: Industry assessment on SDGs in circle 3

Direct SDGs	**Goal 3**: Good health and well-being	**Goal 4**: Quality education	**Goal 6**: Clean water and sanitation	**Goal 7**: Affordable and clean energy	**Goal 11**: Sustainable cities and communities	**Goal 12**: Responsible consumption and production	**Goal 16**: Peace, justice and strong institutions
Applicability (Yes/No)							
If No, why not?							
If yes, how will the industry improve the SDG							
If yes, how will the SDG improve?							
If yes, challenges							

Table 7.4: Industry assessment on SDGs in circle 4

Indirect SDGs	**Goal 1**: No Poverty	**Goal 2**: Zero hunger	**Goal 5**: Gender equality	**Goal 10**: Reduced inequality	**Goal 13**: Climate action	**Goal 14**: Life below water	**Goal 15**: Life on land
Applicability (Yes/No)							
If No, why not?							
If yes, predecessor							
If yes, how will the industry improve the SDG?							
If yes, how will the SDG improve?							
If yes, challenges							

7.3.3 Step 2: Linking technology to SDGs

This step includes the technologies identified in the input stage. Step 2 has to be repeated for each technology identified at the input data. This step provides the industry with information on how the technologies foster SDGs and subsequently the step can assist in identifying which technology(ies) are the best suitable for the action set out to change within the industry. This step is similar to step 1, which makes use of Figure 7.3 to produce four separate tables. However, it reflects on the technology and how the technology can and will be used to foster SDGs, while step 1 reflects the industry alignment with SDGs.

This step if to map out the SDGs aimed to be contributed towards or improved through the action of the technology. Altering the questions in Table 7.1, 7.2, 7.3 and 7.4 to fit the technology environment, Table 7.5, 7.6, 7.7 and 7.8 have been developed, which represents circle 1, 2, 3 and 4 in Figure 7.3 respectively. Starting at Table 7.5 and 7.6, the industry will need to identify "the actors within the technology environment". This question is followed by "actions between the actors to affect the SDG" and lastly the "challenges" identified.

Table 7.5: Technology assessment on SDGs in circle 1

Cornerstone SDGs	**Goal 17**: Partnerships to achieve goal
Actors contributing towards this SDG	
Actions between the actors to affect the SDG	
Challenges	

Table 7.6: Technology assessment on SDGs in circle 2

Cornerstone SDGs	**Goal 8**: Decent work and economic growth	**Goal 9**: Industry, innovation and infrastructure
Action of technology to improve SDG		
How will this technology affect the SDG		
Challenges		

After Table 7.5 and 7.6 have been completed, the possible SDGs that can be improved and/or contribute towards by the technology will need to be identified. In Table 7.7 (refer to circle 3), whether or not the technology can affect the SDG needs to be indicated. This is followed by providing "how the technology can improve the SDG" or "why not". Table 7.7 further probes into "how the SDG will improve" when applying the technology and what the possible "challenges" may arise when trying to improve or contribute towards the SDG.

Table 7.8 represents the fourth and last circle, which contains the indirect SDGs. These SDGs are indirectly affected from the inner circles and can rely on multiple SDGs from circle 3 in Figure 7.3. If the SDG (in circle 4) can be improved, a predecessor(s) is applicable and must be reflected in Table 7.8. These predecessor(s) are also required in step 3 of the framework in order to create a flow chart (refer to Figure 7.5 in step 3). The last few questions focus on "how the technology can improve the SDG" or "why not". Table 7.8 concludes with asking "how the SDG will improve" when applying the technology and what are the possible "challenges" are when trying to improve or contribute towards the SDG.

Table 7.7: Technology assessment on SDGs in circle 3

Direct SDGs	**Goal 3**: Good health and well-being	**Goal 4**: Quality education	**Goal 6**: Clean water and sanitation	**Goal 7**: Affordable and clean energy	**Goal 11**: Sustainable cities and communities	**Goal 12**: Responsible consumption and production	**Goal 16**: Peace, justice and strong institutions
Applicability (Yes/No)							
If No, why not?							
If yes, how will the technology improve the SDG?							
If yes, how will the SDG improve?							
If yes, challenges							

Table 7.8: Technology assessment on SDGs in circle 4

Indirect SDGs	**Goal 1**: No Poverty	**Goal 2**: Zero hunger	**Goal 5**: Gender equality	**Goal 10**: Reduced inequality	**Goal 13**: Climate action	**Goal 14**: Life below water	**Goal 15**: Life on land
Applicability (Yes/No)							
If No, why not?							
If yes, predecessor							
If yes, how will the technology improve the SDG?							
If yes, how will the SDG improve?							
If yes, challenges							

7.3.4 Step 3: Linking industry to technology through the outcomes of previous steps

Step 3 is the final step which concludes the outcomes of steps 1 and 2 by creating a flow chart (refer to Figure 7.5). The industry flow chart describes the SDGs desired to improve. Therefore, in creating a flow chart for each technology, one could identify if there is a specific technology for the industry and SDG driven actions or are whether there multiple technologies to choose from. These flow charts can be utilised as evidence when proposing a new change of technology or action within the industry and describes the benefits of the action and change of technology towards the SDGs.

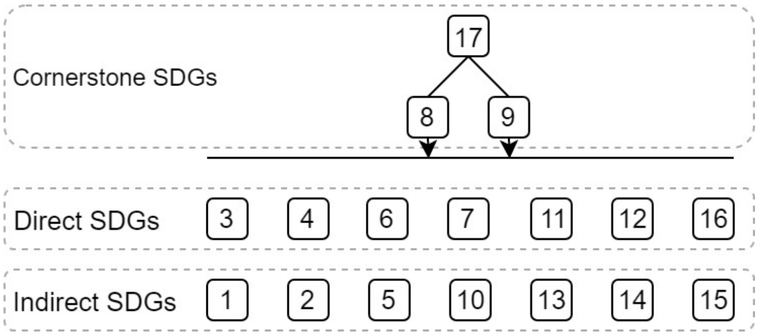

Figure 7.5: SDGs flow diagram

7.3.5 The output

The final outcome of the framework enables any industry to develop a statement indicating the various identified technologies and which technologies support the industry goals. When change within industry is facilitated, it is necessary to build evidence to show why the change occurred and what the benefits (not only for the industry, but the country) to these changes are. The outcome can be created as a full report or as a figure explanation on which technologies fits the industry's goals.

7.4 Validation of the framework

This section provides the validation approach, methodology and the research findings. This section presents Phase 7 of Jabareen's Conceptual Framework Analysis through the validation of the *Industry and technology alignment with SDGs framework*.

7.4.1 Towards a validation approach

A validation process is an integral part of quality assurance of the framework. The validation process aims to determine whether the proposed framework (can be found in Appendix A) perform it intended functions adequately and consistently as specified. For the purpose of this framework, external validation is required in order to ensure quality and applicability.

The three entities (industries, technology and SDGs) have been described and processed in the previous sections of the research project. Also, existing framework, approaches and models have been examined in order to retrieve relevant information to build a framework that is relevant to the existing problem. The framework is further used to provide guidance in terms of choosing between technologies when changing towards SD and contributing and/or improving the SDGs.

7.4.2 Validation methodology and guidelines

The validation process of the present study included collecting qualitative data through subject matter interviews and application on a case study. The validation pathway set out for this study includes semi-structured interviews via SME process and a case study application. Semi-structure interviews consist of a limited number of field experts that participate in the SME validation process.

Semi-structured interviews allowed the author to explain the framework to the experts and answer any other questions that may have arisen. The SMEs were identified based on their background and current field of expertise. Their selection was based upon their relevance towards the implementation of technology for sustainability and research fields such as SD, technologies and knowledge of industries hierarchy. The SMEs embodied different roles within the technology/sustainability field including the research sector. These semi-structured interviews introduced the experts to the background of the project and allowed the expert to grasp a deeper understanding of the research and framework.

The questionnaire, which consisted of pre-determined questions, was used to capture feedback from the experts. These questions varied between open and close ended questions that provided guidance to participants. However, this was managed with open-ended questions in order to prevent restricting participants from elaborating on any perceived shortcomings. The open-ended questions enable the researcher to gather information from the experts regarding concerns or potential shortcomings of the framework. The questionnaire requested feedback on inclusiveness and the potential usefulness of the framework. These questions was based on a likert scale, ranging from 1 to 5. Each question that scored a 3 or lower according to the SME's was further explained.

The second part of the validation process was conducted through the application of a case study. This section aims to provide descriptive, investigative and illustrative findings of the framework. The case study application allows for discussion and observation about practical use of the framework. The framework's practical challenges and requirements become evident and introduced from a different outlook. The case study approach provides the researcher with an up-close, in-depth and detailed examination of an already existing case.

This different outlook of the framework exists within a case study due to the similarities between reality and case studies. Limitations of case studies include manipulative information and/or information rooted in the way they have been used in reality. Due to these factors, it remains challenging to validate the framework across a wide variety of circumstances.

7.4.3 Results and discussion

This section discusses the results of the interviews with the SMEs and addresses the problems that arose. Table 7.9 lists the various SMEs that participated in this validation process. Their selection was based upon their relevance towards the implementation of technology for sustainability and research fields such as SD, technologies and knowledge of various industries. SME 5 did not complete a questionnaire, however did provide sufficient verbal feedback and guidance during the validation process of the framework.

Each section within the questionnaire (design requirements, strategic decision management, framework design, input, process, output and overall review) were individually reported on. After each section of questions, the identified problem areas are identified and solutions are given to these specified problems.

Table 7.9: Professional interviewees

Validator	Occupation and affiliation
SME 1	Green technology manager at a non-profit organisation
SME 2	Energy Programme manager at a non-profit organisation
SME 3	Lecturer and researcher in the field at a university
SME 4	Project officer and Geoscientist at a non-profit organisation
SME 5	Associate professor in the field at a university

7.4.3.1 Design requirements

Table 7.10 contains the feedback from the SMEs on the design requirements of the framework set out in this study. One SME doubted the first design requirement and questioned whether the framework is a generic model that is applicable to most or all industries. As previously stated and assumed in the framework introduction, SDG 8, 9 and 17 are cornerstones of any given industry. Therefore, each industry affects different SDGs within the framework. However, each industry consists of various entities within the industries, forcing the entities inside or outside a specific industry to form partnerships in order to strive towards SDGs.

According to the SME reviews of the framework, it became was evident that the SMEs are unsure whether the framework is user friendly or not. This may be due to the complexity in nature within any given framework. This framework is based on qualitative data and does not include other factors which may influence the decision maker.

The SMEs response to the design requirement and connecting entities, were negatively influenced due to factors that were not included in the framework. One SME stated that the decision maker's final decision is based on a budget only. Therefore, the design requirement is sufficiently in terms of this framework and its exclusions.

One design requirement that is evidently a problem according to the reviews of SMEs is that of whether the framework can be used to guide choice of technologies. It is clear (refer to comments in Appendix B) that the SMEs feedback is reliant on the financial feedback and analysis of the technology and whether the technology is chosen or not. This framework cannot be solely used to choose between technologies, but can be used in combination with other frameworks and tools that include other factors, entities and participants, such as interactions between technology, policy/power/politics, economics/business/markets, and culture/discourse/public opinions (Geels, 2011). This framework is designed to guide industries towards SD when choosing technologies.

Problem areas

Through these questions, it was not expected that any problems would be evident or that the framework needed to undergo any changes. However, it is evident that the framework lacked in explaining how it was developed, how it functions and how to implement it.

Solutions and/or changes

These minor problems identified did not result in changes being made to the framework, but did make it more water tight. More evidence is provided in Section 7.2 and more detailed description of the framework is provided.

7.4.3.2 Strategic decision management

The strategic decision management feedback was mainly fell in the "unsure" category (refer to Table 7.11) due the issue of financial implications of projects. One SME indicated that they strongly agree to the framework if SDGs are the only decision matrix in choosing technologies. Another SME commented that the framework can be used to select the impact technology, providing another factor of consideration for the decision maker. Together with other frameworks, models and approaches, this model could have an impact on the decision maker's decision.

Table 7.10: Design requirements validation results

Validation questions	Strongly Disagree	Disagree	Unsure	Agree	Strongly Agree
Generic model					
To what extent can this framework relate to the current number of industries?	0	1	0	3	0
User friendly					
Is the framework sufficiently introduced and explained?	0	0	1	3	0
Does the framework flow accordingly?	0	0	0	4	0
Ease of use by the user?	0	0	3	1	0
Industry identifying contribution towards SDGs					
During the use of the framework, is the evaluation of industry towards SDGs possible?	0	0	1	3	0
Is the outcome of the industry contributions towards SDGs realistic and reachable?	0	0	1	3	0
Connect entities (Industry, technologies and SDGs)					
To what extent is the connection between entities realistic and feasible?	0	0	2	2	0
Is the framework connecting the entities applicable and sufficient?	0	0	3	1	0
Guidance for choosing technologies					
To what extent does the framework provide realistic and feasible guidance?	0	0	3	1	0
Is the guidance towards technology effective and sufficient?	0	1	1	2	0
Recognise and improve sustainability					
Does this framework recognise sustainability realistically?	0	0	1	3	0
To what extent does the framework improve the sustainability?	0	0	1	3	0

Feedback conclusion

Given that the feedback received leant towards the lack of financial information within the framework, there were no problems identified within the framework, nor were there any changes made to the strategic decision management component of the existing framework.

7.4.3.3 Framework design and framework input

The feedback received on the design of the framework was very positive, evident in Table 7.12 and 8.2.1. In both the design and input sectors, there were positive comments. According to one SME, the framework design is logically sound and requires proper implementation to reach each

Table 7.11: Strategic decision management validation results

Validation questions		Strongly Disagree	Disagree	Unsure	Agree	Strongly Agree
To what extent can this framework influence the decision maker?		0	0	3	1	0
How much of a difference can the output have within the decision-making process?		0	0	4	0	0
Did the researcher provide a	plausible tool that influence the decision maker?	0	0	2	2	0
	framework that includes logical reasoning?	0	0	1	3	0
	framework that is compelling enough to affect the decision maker?	0	0	2	2	0

goal. The input required for the framework is achievable with proper evaluation.

Table 7.12: Framework design validation results

Validation questions	Strongly Disagree	Disagree	Unsure	Agree	Strongly Agree
Is the layout of circle 1 and 2 applicable, practically feasible and logical?	0	0	0	4	0
Circle 3, to what extent is this circle applicable, practically feasible and logical?	0	0	0	4	0
Circle 4, to what extent is this circle applicable, practically feasible and logical?	0	0	0	4	0
Is the design of the framework sufficient, applicable and feasible?	0	0	2	2	0

Feedback conclusion

Due to the positive feedback received from the SMEs, there were no problem areas identified within the framework design and input sectors. As such, no framework changes were implemented following the framework design and input feedback.

Table 7.13: Input validation results

Validation questions	Strongly Disagree	Disagree	Unsure	Agree	Strongly Agree
To what extent is the industry action applicable and feasible?	0	0	1	3	0
Is it possible to identify technologies as an input?	0	0	0	3	1
Within practice, is the input practically achievable?	0	0	1	3	0

7.4.3.4 Process

Step 1

The overall feedback of step 1 from the SMEs was positive with some comments to support their vision. This step having a direct impact on the success of the industry was one of the comments made. Other comments touched on missing information that was added to the content of section 7.2.

Step 2

Feedback on step 2 of the framework is provided in Table 7.14 and was positive. SMEs commented that cleaner technology may have effects on the industry that other technologies may not have. These comments support that this step was thoroughly executed and well designed in order to identify the differences between technologies after implementing the framework.

Step 3

The SMEs feedback on step 3 echos previous concerns about the financial implications on the decision maker. SMEs commented that it was complicated to understand at first, but after the first time it is easier.

Feedback conclusion

Valuable feedback was received from this sector and was processed to form part of the refined framework. This includes information (based on qualitative data) that is useful to the user.

Due to the positive feedback on step 2 of the framework, no problem areas were identified in this step. As such, no changes after the feedback on step 2 were made.

Step 3 introduces problem around the financial implications of the framework, a problem outside the scope of this project. The framework does not provide any information regarding the financial details of the technologies. Therefore, no changes were made to step 3 of the framework following this feedback.

7.4.3.5 Output

Table 7.15 provides the feedback from the SMEs and shows that SMEs think that this framework's output is valid and worthy. Some comments in this section include that this output is worthy but lacks sufficiency. This may explained the lack of financial information that is outside the scope of this framework. Other SMEs indicated that this output and framework would work well if the data were quantitative and considered financial factors.

Feedback conclusion

The output of the framework was found to be worthy and given the positive feedback from the SMEs, the output of the framework had no problems within the scope of the framework. As such, no changes to the output of this framework were made.

7.4.3.6 Overall review

The overall review of the framework are positive, as evident in Table 7.16. Comments in this section were fairly positive and some of the comments provided assumptions. An example of one assumption is that the framework should assume partnerships are working. One SME commented that this framework is a good way of thinking about how to influence the SDGs and how these SDGs can be linked.

Feedback conclusion

There were no real concerns regarding the framework or the overall review of the framework. Information received from the SMEs was added to the body of the framework and no physical changes to the layout or design of the framework were made.

Table 7.14: Process validation results

Validation questions		Strongly Disagree	Disagree	Unsure	Agree	Strongly Agree
Step 1	TABLE 7.1 - To what extent is this table applicable, practically feasible and logical?	0	0	0	4	0
	TABLE 7.2 - To what extent is this table applicable, practically feasible and logical?	0	0	0	4	0
	TABLE 7.3 - To what extent is this table applicable, practically feasible and logical?	0	0	0	4	0
	TABLE 7.4 - To what extent is this table applicable, practically feasible and logical?	0	0	0	4	0
	Overall flow of tables, information regarding the tables and practicality of the tables?	0	0	2	2	0
Step 2	TABLE 7.5 - To what extent is this table applicable, practically feasible and logical?	0	0	0	4	0
	TABLE 7.6 - To what extent is this table applicable, practically feasible and logical?	0	0	0	4	0
	TABLE 7.7 - To what extent is this table applicable, practically feasible and logical?	0	0	1	3	0
	TABLE 7.8 - To what extent is this table applicable, practically feasible and logical?	0	0	1	3	0
	Overall flow of tables, information regarding the tables and practicality of the tables?	0	0	0	4	0
Step 3	Is the flow diagram (Figure 7.5) appropriate for practical use?	0	0	1	3	0
	Does step 3 provide the decision maker with suitable information?	0	0	1	3	0
	To what extent does step 3 provide sufficient and effective guidance?	0	0	2	2	0

Table 7.15: Output validation results

Validation questions	Strongly Disagree	Disagree	Unsure	Agree	Strongly Agree
To what extent are the outputs valid?	0	0	2	2	0
How worthy are the outputs of the framework?	0	0	2	2	0
Does the framework provide appropriate, suitable and sufficient evidence?	0	0	1	3	0

Table 7.16: Validation results of overall review

Validation questions	Strongly Disagree	Disagree	Unsure	Agree	Strongly Agree
To what extent do you agree that this framework does what it says it does?	0	0	1	2	1
How strongly do you agree that this framework is of high quality?	0	0	2	2	0

7.5 Chapter 7: Conclusion

Chapter 7 presents the design and development of the conceptual framework. The prevailing literature forms the foundation of the framework as it was developed from the culmination of findings in preceding chapters of this thesis. Phase 4 through to Phase 7 of Jabareen's Conceptual Framework Analysis was completed in this chapter. The product of this is a refined framework. This chapter also includes the recommendations of the validation process. The chapter concludes with the first part of the validation process. The results are discussed and the necessary changes have been made to the framework. The next chapter tackles the second part of the validation process, which consists of a case study.

Chapter 8

A case study of industry and technology alignment with SDGs within the South African energy sector

This chapter first outlines the purpose of the case study and thereafter, the relevant documentation the case study is based on is discussed. The case study process and outcome are represented in section 8.2. Thereafter, the chapter concludes with a case study discussion.

8.1 Introduction

A case study exposes the framework to inspection and aims to explore and discuss the practical application of the framework (Robert, 2014). It also provides a retrospective view on the research used to develop the framework. The case study exploits the strengths and weaknesses of the framework and highlights the areas for future research. A case study provides both explorative and evaluative aspects of the framework and tests the applicability of the framework.

The present case study on the *Industry and technology alignment with Sustainable Development Goals (SDGs) framework* is to gain more in-depth practical insight on how the framework performs. Currently, South Africa is investing in the energy sector to secure energy generation sustainability (South African Government News Agency, 2018). Therefore, the Integrated Resource Plan (IRP) was selected as the case to investigate as the context is relevant to the work done in this study.

The data used in this case study are gathered from a number of reports, i.e. the IRP report (Department of Energy, 2018), Socio-Economic impact assessment system report (Department of Planning Monitoring and Evaluation, 2018) and the Power Generation Technology Data for Integrated Resource Plan of South Africa report (Electric Power Research Institute (EPRI), 2010).

At the end of the interview (refer to section 7.4.2 and 7.4.3 where the same SMEs for the validation of the case study are represented), the case study was validated through a discussion about the functionality of the framework within the case study.

8.2 Application of the framework

The case study is structured in the same manner in which the framework was explained in section 7.2. The first section explains the input for the framework, which is followed by steps one (linking of the industry to SDGs), two (linking technology to SDGs) and three (linking industry to technology through the outcomes of step one and two). The case study is concluded in section 8.2.5, in which the output is discussed.

8.2.1 The input

In order for any industry to make use of the framework it is necessary that the industry has the inputs required to start with the framework. The following inputs are required:

Industry type: Energy

Area of industry: Energy generation

Technologies considered: Coal technology, Nuclear technology, Gas technology and Renewable technology

Referring to section 7.3.1, the specific industry that uses this framework, is the first input required by the framework. The second input, area of industry, refers to the operation the industry aims to change. The third input refers to the technologies identified by the industry which they aim to implement for future use in that specific activity within the industry.

8.2.2 Step 1: Linking industry to SDGs

The first step is to set out SDGs that the industry aims to contribute towards. Each circle within Figure 7.3 is changed (through applying Figure 7.4) into tables. These tables are presented in 8.1 - 8.4 and describes how the industry is trying to contribute towards achieving the SDGs through the industry actions.

Table 8.1 contains information regarding the partnership that could contribute toward SDG 17, but also act as the foundation of the framework. This table includes partnerships, both inside and outside of the specified industry. Table 8.1 contains information such as the actors which can contribute and/or improve the current state of the SDG and contribute towards the foundation of the framework.

Table 8.1 further discusses actions between the actors that could potentially contribute and/or improve the SDG. These actions may contribute toward the bigger picture of providing a building block for achieving and/or contributing to the outer circles of the framework. Potential challenges that may arise through the implementation of the action are identified in the last row of Table 8.1.

The second part of the cornerstone SDGs of this framework is presented in Table 8.2. This table focusses on the specific actions that will contribute and/or improve SDG 8 or 9. These actions may or may not follow on the actions set out in Table 8.1, but act as a fundamental part of the framework. The Table allows the industry to identify ways in which the specified actions may affect the SDG and the potential challenges it includes. Table 8.1 and 8.2 act as cornerstones when linking the energy sector with SDGs and facilitates industry to strive towards various other direct and indirect SDGs in circle 3 and 4 of Figure 7.3 of the framework.

The third circle is represented in Table 8.3 and contains the direct SDGs of the framework. Table 8.3 allows the industry to identify whether the SDGs (SDGs 3, 4, 6, 7, 11, 12, and 16) are relevant to their actions. After the industry have chosen the applicable SDGs that are affected by their actions and change, they provide information regarding how the industry could improve and/or contribute towards the SDG and in ways the SDG could improve. Table 8.3 allows the industry to identify the relevant challenges that could be faced through each SDG's actions and improvements.

Through the identification process of applicability of the SDGs, Table 8.3 provides sufficient information (industry input) on why the specific SDG is not applicable and/or could not contribute.

The last circle, circle 4, provides the indirect SDGs (SDGs 1, 2, 5, 10, 13, 14 and 15) of the framework and is constructed in Table 8.4. This table allows the industry to identify the applicable SDGs to their actions and contributions. The SDGs that are applicable to the energy sector further identifies the predecessor of the SDG. Table 8.4 contains more information regarding how the industry aims to improve and/or contribute towards the applicable SDGs, how these SDGs could change and the relevant challenges that could be faced through each SDG's actions and improvements.

Table 8.4 provides information on why the SDG is not applicable to the industry actions and contributions.

Table 8.1: Circle 1 - Energy industry

Cornerstone SDGs	**Goal 17**: Partnerships to achieve goal					
Actors contributing towards this SDG	Department of Energy	Government (State owned Entities)	Private sector	Investors	Research & Development	Technology suppliers
Actions between actors to affect the SDG	Open communication platform and flow of information to ensure no hidden agendas or corruption. Form of partnerships to improve					
Challenges	Policy difficulties and corporate culture differences					

Table 8.2: Circle 2 - Energy industry

Cornerstone SDGs	**Goal 8**: Decent work and economic growth	**Goal 9**: Industry, innovation and infrastructure
Action of industry to improve SDG	Focussing on new projects for the energy sector	Improving on old technology and implementing new technology
How will this action affect the SDG	New project = New jobs available = economic growth	Through the continuous improvements it will support the SDG by keeping up with the technology trend and ensuring that enhancements do happen
Challenges	The new projects may put old technology within the energy sector out of existence that may affect other jobs	Expensive, inefficient and a lack of expertise within the field

Table 8.3: Circle 3 - Energy industry

Direct SDGs	**Goal 3**: Good health and well-being	**Goal 4**: Quality education	**Goal 6**: Clean water and sanitation	**Goal 7**: Affordable and clean energy	**Goal 11**: Sustainable cities and communities	**Goal 12**: Responsible consumption and production	**Goal 16**: Peace, justice and strong institutions
Applicability (Yes/No)	No	No	No	Yes	Yes	Yes	No
If No, why not?	According the IRP 2018 the plan is to enable new technology to provide solutions which aims does not directly affect this goal	By changing the technology within the energy sector will not enable education to improve directly. Thus, making quality education not applicable	By changing the technology will not be able to help or improve Goal 6 to generate clean water and sanitation				Currently the goal why the technology change is happening is not to focus on peace, justice and strong institutions, making this goal not applicable
If yes, how will the industry improve the SDG				By changing the energy generation technology, this goal is the main aim to improve	Providing for rural areas and communities electricity	Changing the technology to use for energy generation to consume responsible and producing sufficient energy	
If yes, how will the SDG improve?				By changing the old technology for the new technology	Connecting the communities to a wider system and don't "stay behind"	Change the impact on the environment	
If yes, challenges				Affordability, infrastructure and skills required	Lack of skills, underestimate usage and infrastructure necessary to build such a system	How much resources are necessary for such a change in technology and will it uphold its capacity 7	

Table 8.4: Circle 4 - Energy industry

Indirect SDGs	**Goal 1**: No Poverty	**Goal 2**: Zero hunger	**Goal 5**: Gender equality	**Goal 10**: Reduced inequality	**Goal 13**: Climate action	**Goal 14**: Life below water	**Goal 15**: Life on land
Applicability (Yes/No)	No	No	Yes	Yes	Yes	Yes	Yes
If No, why not?	The action why the energy industry changing the technology doesn't include poverty as a primary result of new technology implantation. It has a slight effect on people receiving electricity, however they might not know how to benefit from this idea	By changing the technology within the energy sector has little to none effect on the food security and zero hunger goal					
If yes, predecessor			11	7, 11	7, 12	7, 12	7, 11, 12
If yes, how will the industry improve the SDG?			Generating jobs through new projects. Thus, providing an opportunity to close the gender inequality gap	Generating jobs through new projects. Thus, providing an opportunity to close inequality gaps where necessary	Industry want to change towards cleaner energy that is sufficient for the demand	Swopping old technology with new technology that produces fewer toxic gasses that indirectly effects the life below water	Through the improvements of the technology it is able to promote the life on land through generating clean energy, creating sustainable communities and producing while consuming responsible
If yes, how will the SDG improve?			Gender inequality will decrease	Inequality will reduce one opportunity have been filled with people that has been unfortunate	Producing less toxics and acting towards responsible usage	Through controlling the climate, it is able to preserve the quality of the oceans	Through limiting and controlling the damages done on the environment, it is able to preserve the life on land longer
If yes, challenges			Unskilled necessary workforce	No appropriate skilled workforce	Financial strains, infrastructure and plausibility	Slow progress might not be visible in the short term, multiple factors that contribute	Slow progress might not be visible in the short term, multiple factors that contribute

Concluding remarks of Step 1

Step one discusses the direction the energy industry strives towards (referring to SDGs) through the implementation of other technologies. It is evident in Table 8.1 that there are numerous challenges that will be faced in order to achieve full transition towards other technologies.

According to the case study documents, the energy sector strives for a more prosperous future with an outlook on technologies that are beneficial for the environment and human beings. These tables consisting of information from the energy sector information, contains valuable data and ensures that there are opportunities for growth within the energy sector.

The prosperous future and outline of SDGs the energy sector strive towards is evident in step 3 and Figure 8.1 illustrates how the industry connects to the SDGs.

8.2.3 Step 2: Linking technologies to SDGs

The second step entails linking of technologies (specified in the input) to SDGs. This step contains similar tables to step one (refer to section 8.2.2) and shows the SDGs that are aimed to improve through the help of specific technologies. Tables 8.5 - 8.20 show the contributions towards relevant/selected SDGs and how the technology can improve and/or contribute to the SDGs. The four input technologies, identified in section 8.2.1 can be seen below in the different sub-sections.

Similar to step 1, Tables 8.5, 8.9, 8.13 and 8.17 contains information about the partnership that could contribute to SDG 17. These table include partnerships, both inside and outside of the specified technology field. Tables 8.5, 8.9, 8.13 and 8.17 contain information on the actors (within the technology environment) that can contribute and/or improve the current state of the SDG and contribute to the foundation of the framework.

The first circle was constructed into table format and Tables 8.5, 8.9, 8.13 and 8.17 were the outcome of various technologies. These tables discuss actions between the actors that could potentially contribute to and/or improve the SDG. These actions may make contributions towards the bigger picture of providing a building block for achieving and/or contributing to the outer circles of the framework. The potential challenges, within the technology environment that these actions may include through the implementation of the action is identified in the last row of Tables 8.5, 8.9, 8.13 and 8.17.

The cornerstones of the framework continue in Tables 8.6, 8.10, 8.14 and 8.18. These tables focus on the specific actions that the technology could enhance and how it will contribute and/or improve SDG 8 or 9. The tables allow the industry to identify actions and challenges in which the technology would contribute to and/or improve SDGs. Tables 8.5, 8.9, 8.13 and 8.17 and Tables 8.6, 8.10, 8.14 and 8.18 act as the cornerstones when linking the technologies with SDGs. These actions directly and indirectly affect the SDGs in circle 3 and 4 of Figure 7.3 of the framework.

The framework's third circle is represented in Tables 8.7, 8.11, 8.15 and 8.19. These tables contain the direct SDGs of the framework. Tables 8.7, 8.11, 8.15 and 8.19 allow the industry to identify whether the SDGs (SDGs 3, 4, 6, 7, 11, 12, and 16) are relevant to the technology and their attributes. The technology attributes, affecting some SDGs then identifies how the SDG improves, whereafter, the potential challenges are identified.

The SDGs that were not applicable to the technology are provided in Tables 8.7, 8.11, 8.15 and 8.19, which provide sufficient information as to why the technology would have little to no impact on the SDG.

Circle 4 consists of the indirect SDGs (SDGs 1, 2, 5, 10, 13, 14 and 15) and is presented in Tables 8.8, 8.12, 8.16 and 8.20. The applicability of the technology to the indirect SDGs is evident in these tables. The SDGs that were applicable was further discussed and predecessors were identified. Those that were not affected by the technology and made no impact or contribution to the specific SDGs was discussed.

Coal Technology

Table 8.5: Circle 1 - Coal Technology

Cornerstone SDGs	**Goal 17**: Partnerships to achieve goal					
Actors contributing towards this SDG	Department of Energy	Government (State owned Entities)	Private sector	Investors	Research & Development	Technology suppliers
Actions between actors to affect the SDG	Development of new relationships to generate cleaner coal technologies					
Challenges	The current technology challenges for coal technology is to come up with a innovation plan to generate cleaner energy with coal. Challenges includes jobs lost and industry strains on working environment					

Table 8.6: Circle 2 - Coal Technology

Cornerstone SDGs	**Goal 8**: Decent work and economic growth	**Goal 9**: Industry, innovation and infrastructure
Action of technology to improve SDG	Energy sector switch towards other technologies until cleaner and more sufficient coal technologies arise. Thus, providing the opportunity to elaborate in the R & D department.	Coal technologies has to catch up on the other technologies. There is opportunities in innovation and producing solutions to coal technologies with the current infrastructure as a base.
How will this technology affect the SDG	This action will affect the Goal in a positive and negative way. Jobs in other actors is created while jobs are being lost by those who had a solid foundation.	This new innovation within the coal technologies provides a good base for this goal. Endless possibilities exist in R& D.
Challenges	Challenges is to keep the people employed and don't lose jobs opportunities.	The challenge is to innovate coal technologies that is cleaner and more sufficient.

Table 8.7: Circle 3 - Coal Technology

Direct SDGs	**Goal 3**: Good health and well-being	**Goal 4**: Quality education	**Goal 6**: Clean water and sanitation	**Goal 7**: Affordable and clean energy	**Goal 11**: Sustainable cities and communities	**Goal 12**: Responsible consumption and production	**Goal 16**: Peace, justice and strong institutions
Applicability (Yes/No)	No	No	No	No	No	Yes	No
If No, why not?	Coal technology has close to zero effect on the health industry. Thus, coal technology is not applicable	Coal technology cannot provide quality education to learners and students. It has no effect on Goal 4	By creating a solution for clean water and sanitation by generating electricity through coal technology has no linkage and no effect on one another.	Currently the coal technology is not clean energy. Thus, by implementing research and development the coal industry can revive if and only if it can produce solutions to fit prosperous futures.	Coal technology deepens on the coal the earth produces. Thus, it is unsustainable for the future and cannot currently be a solution for this goal		Coal technology and the justice system has no effect on one another. Thus, it is not applicable.
If yes, how will the technology improve the SDG						By implementing certain technologies, it is able to generate more electricity from less coal. Thus, enhancing the technology for the same output with less input.	
If yes, how will the SDG improve?						By putting less input (coal) into the system, it is able to supply electricity for longer on the same amount of coal.	
If yes, challenges						More expensive technology than alternations, coal supply running dry	

Table 8.8: Circle 4 - Coal Technology

Indirect SDGs	**Goal 1**: No Poverty	**Goal 2**: Zero hunger	**Goal 5**: Gender equality	**Goal 10**: Reduced inequality	**Goal 13**: Climate action	**Goal 14**: Life below water	**Goal 15**: Life on land
Applicability (Yes/No)	No	No	No	No	Yes	Yes	Yes
If No, why not?	New or old technology has no effect on the poverty in the country. Thus, it is not applicable	People won't die from hunger whether new or old coal technologies is used. This said, it has no effect on Goal 2	By providing little to none working opportunities to the community, it is unable for coal technologies to provide a good outcome for gender equality	By retrenching workers in the current stage, it is not possible for the coal technology sector to reduce the inequalities within the country			
If yes, predecessor					12	12	12
If yes, how will the technology improve the SDG?					By introducing new technology that produces less harm to the environment	By introducing new technology that produces less harm to the environment	By introducing new technology that produces less harm to the environment
If yes, how will the SDG improve?					The accumulative amount of harm to the environment is less when applying new technologies or making use of alternatives	The accumulative amount of harm to the environment is less when applying new technologies or making use of alternatives	The accumulative amount of harm to the environment is less when applying new technologies or making use of alternatives
If yes, challenges					Can be costly, lack of skilled workforce and investment constraint	Can be costly, lack of skilled workforce and investment constraint	Can be costly, lack of skilled workforce and investment constraint

Nuclear Technology

Table 8.9: Circle 1 - Nuclear Technology

Cornerstone SDGs	**Goal 17**: Partnerships to achieve goal					
Actors contributing towards this SDG	Department of Energy	Government (State owned Entities)	Private sector	Investors	Research & Development	Technology suppliers
Actions between actors to affect the SDG	The actors within the energy industry and nuclear technology would have to implement two strategies which is to maintain the current infrastructure and improving/implementing new nuclear technologies respectively. Through this, the nuclear technology would maintain their share of supplying with a stable growth					
Challenges	Information regarding the maintenance of the technology and real time data is incorrect or lost along the way will enable challenges for the innovation of new technology.					

Table 8.10: Circle 2 - Nuclear Technology

Cornerstone SDGs	**Goal 8**: Decent work and economic growth	**Goal 9**: Industry, innovation and infrastructure
Action of technology to improve SDG	Through constant growth within the nuclear technology environment it is able to achieve this goal	Innovation and infrastructure are the two components the industry has to upkeep in order to achieve the end goals
How will this technology affect the SDG	This action will ensure stable economic growth and minimum job losses	This will ensure that the industry keep up with the latest technology while achieving the aimed goals
Challenges	Infrastructure stability and maintaining the system	Reaching the ceiling of nuclear technology development

Table 8.11: Circle 3 - Nuclear Technology

Direct SDGs	**Goal 3**: Good health and well-being	**Goal 4**: Quality education	**Goal 6**: Clean water and sanitation	**Goal 7**: Affordable and clean energy	**Goal 11**: Sustainable cities and communities	**Goal 12**: Responsible consumption and production	**Goal 16**: Peace, justice and strong institutions
Applicability (Yes/No)	No	No	No	No	Yes	Yes	No
If No, why not?	Due the fact that nuclear technology has no effect on the health and well-being goal, this is not applicable	The primary facts of nuclear technologies have no intentions on improving the education system. Thus, making this goal not applicable	New or improved nuclear technologies has no influences on clean water and sanitation within a country	According to the IRP it is evident that nuclear technology not supportive is towards clean energy, it has a negative influence and cannot improve the goal			Nuclear technologies and improvements cannot improve the country's justice system and can't bring peace making this goal irrelevant
If yes, how will the technology improve the SDG					By continuing to implement and improve nuclear technologies to support the overall goal of achieving full sustainability of cities and communities	By implementing new nuclear technologies on a strategy bases, it is possible to produce the necessary demand of electricity while consuming responsibly	
If yes, how will the SDG improve?					This technology supports the sustainability factor and can improve the progress made towards this goal of sustainable cities	The less nuclear technologies consume, the longer it can be used and the more sustainable it becomes	
If yes, challenges					The technology may not be the cleanest of all technologies and may affect life on land	Nuclear technologies may be harmful to environment after use	

Table 8.12: Circle 4 - Nuclear Technology

Indirect SDGs	**Goal 1**: No Poverty	**Goal 2**: Zero hunger	**Goal 5**: Gender equality	**Goal 10**: Reduced inequality	**Goal 13**: Climate action	**Goal 14**: Life below water	**Goal 15**: Life on land
Applicability (Yes/No)	No	No	Yes	Yes	Yes	Yes	Yes
If No, why not?	Implementing new technology may not be helpful by providing the less fortunate with electricity	By providing the hunger with electricity will not effectively affect the hunger issue					
If yes, predecessor			11	11	12	12	11, 12
If yes, how will the technology improve the SDG?			Creating a space for people to make a difference within a wealthy economy can creating jobs	Providing a healthy space for people to promote themselves	By acting (consuming less with improved technologies) and implementing cleaner technologies if possible	By implementing and improving the current technology	New technology and improve current technology to promote sustainability
If yes, how will the SDG improve?			Creating jobs within a sustainable community enables gender equality to depreciate.	People can uplift themselves within the community and promote their standards	Less fossil fuels end up in the environment means that the earth can be sustained over a longer period of time	This will help prevent changes within the eco-system and more specifically the ocean	This will improve the current state of living for everything on earth.
If yes, challenges			Uneducated and under skilled workforce	Inadequate infrastructure and unskilled communities	Too much electricity needed for the system	Apart of a bigger system, unable to undo changes	Resistance to change within the environment

Gas Technology

Table 8.13: Circle 1 - Gas Technology

Cornerstone SDGs	**Goal 17**: Partnerships to achieve goal					
Actors contributing towards this SDG	Department of Energy	Government (State owned Entities)	Private sector	Investors	Research & Development	Technology suppliers
Actions between actors to affect the SDG	Current data need to be available to all actors. Communication lines where possibilities within the system need to be revised by all participants					
Challenges	Lack of attention to detail, too much information					

Table 8.14: Circle 2 - Gas Technology

Cornerstone SDGs	**Goal 8**: Decent work and economic growth	**Goal 9**: Industry, innovation and infrastructure
Action of technology to improve SDG	Implementing and maintaining the infrastructure of the current system	Improve current technology and infrastructure
How will this technology affect the SDG	By upholding the current system, it is possible promote stable work opportunities and economic growth	Improving the current systems enable this goal to improve and multiple downstream goals
Challenges	Inflation, import cost and international currency conversion	Cost, technology disadvantages and competition

Table 8.15: Circle 3 - Gas Technology

Direct SDGs	**Goal 3**: Good health and well-being	**Goal 4**: Quality education	**Goal 6**: Clean water and sanitation	**Goal 7**: Affordable and clean energy	**Goal 11**: Sustainable cities and communities	**Goal 12**: Responsible consumption and production	**Goal 16**: Peace, justice and strong institutions
Applicability (Yes/No)	No	No	No	No	No	Yes	No
If No, why not?	Gas technology cannot improve the health system and has no effect on the industry or vice versa	Education system is not applicable to the technology within the energy sector. Thus, making this goal not applicable	Gas technology for power generation has no effect on or cannot contribute towards clean water and sanitation making this goal not applicable	Gas technology has no clean energy availability and is on the edge of being expensive due to the rising prices	Natural gasses are not sustainable and the future of sustainable cities and communities can't include technology that depends on natural resources		The technology has no effect on this goal and cannot improve on contribute towards this goal
If yes, how will the technology improve the SDG						Implementing new technology that uses less fuels to generate power	
If yes, how will the SDG improve?						Using less will make less fossil fumes and less damage to the environment	
If yes, challenges						Expensive to maintain and implement, rising gas prices	

Table 8.16: Circle 4 - Gas Technology

Indirect SDGs	**Goal 1**: No Poverty	**Goal 2**: Zero hunger	**Goal 5**: Gender equality	**Goal 10**: Reduced inequality	**Goal 13**: Climate action	**Goal 14**: Life below water	**Goal 15**: Life on land
Applicability (Yes/No)	No	No	No	No	Yes	No	Yes
If No, why not?	New gas technology will not be able to reduce poverty and has no applicability towards this goal	Gas technology cannot produce food for those who doesn't have, making this goal not applicable	Gas technology cannot create a sustainable environment to thrive in where gender equality can be reduced	Reducing inequalities cannot be achieved through this gas technologies because of the unsustainability of the technology and gas itself.		New gas technology has little to no effect on the life below water and is not applicable to this action	
If yes, predecessor					12		12
If yes, how will the technology improve the SDG?					Implanting improved gas technologies		Implementing new and improved technologies
If yes, how will the SDG improve?					Using less gasses and emitting fewer toxic fumes into air		Reserve natural gasses and less damage to the air and earth
If yes, challenges					Ongoing cost and maintenance		Growing population with growing consumption and limited natural resources

Renewable Technology

Table 8.17: Circle 1 - Renewable Technology

Cornerstone SDGs	**Goal 17**: Partnerships to achieve goal					
Actors contributing towards this SDG	Department of Energy	Government (State owned Entities)	Private sector	Investors	Research & Development	Technology suppliers
Actions between actors to affect the SDG	Communication plays a critical role while open innovation platforms can enable the industry to enhance faster and adapt to changes while necessary					
Challenges	Economic negativity while open innovation, patent control and research gaps					

Table 8.18: Circle 2 - Renewable Technology

Cornerstone SDGs	**Goal** 8: Decent work and economic growth	**Goal 9**: Industry, innovation and infrastructure
Action of technology to improve SDG	Implementing new technology in the field and creating new projects	Constant building on the infrastructure and continuous improvements on innovation platforms
How will this technology affect the SDG	This new project creates jobs and create wealth within the economy and downstream help improve goals	Upkeep to innovations around the world and improve on current structures and technology
Challenges	Cost, unskilled workforce	Hidden costs and unfeasibility

Table 8.19: Circle 3 - Renewable Technology

Direct SDGs	**Goal 3**: Good health and well-being	**Goal 4**: Quality education	**Goal 6**: Clean water and sanitation	**Goal 7**: Affordable and clean energy	**Goal 11**: Sustainable cities and communities	**Goal 12**: Responsible consumption and production	**Goal 16**: Peace, justice and strong institutions
Applicability (Yes/No)	Yes	No	Yes	Yes	Yes	Yes	No
If No, why not?		Minimal affects to the education system are in order when applying new technology for the energy sector					There are no specific measures in which this change in technology generation energy can improve the justice system. Thus, this goal is not applicable
If yes, how will the technology improve the SDG	Implementing renewable technologies near and at health institutions		Renewable technology can be able to generate clean water for rural communities.	Renewable energy can be downscaled to support smaller communities and provide clean and affordable energy for the community	Implementing renewable energy will promote sustainable cities and communities the best in all forms of technology available	Implementing new technology that consume less and provide more	
If yes, how will the SDG improve?	Improve the energy provided to these facilities with a constant feed with minimal outages.		By providing them with such technologies, enables the community to have clean water for everyday use	The communities won't be left behind with the technology enhancements and can build economic wealth through the energy provided.	The most improvements would be evident when renewable technology is implemented. In terms of sustainable energy and promoting cities and communities	By using less to none of the earth's resources reserves the earth we all live on and could go on while the technology is in working order	
If yes, challenges	Lack of infrastructure and cost		Corruption and over usage of supply	Underkilled labour, maintenance, unfeasible area	Cites for suitable renewable energy, policy restrictions and under developed infrastructure	Inefficient technology, costly	

Table 8.20: Circle 4 - Renewable Technology

Indirect SDGs	**Goal 1**: No Poverty	**Goal 2**: Zero hunger	**Goal 5**: Gender equality	**Goal 10**: Reduced inequality	**Goal 13**: Climate action	**Goal 14**: Life below water	**Goal 15**: Life on land
Applicability (Yes/No)	No	No	Yes	Yes	Yes	Yes	Yes
If No, why not?	By providing energy to the poorest of poor will not end poverty and there is no proof that it will help the poverty goal	Energy to the people with no food will not survive on the electricity provided for them. It would take time and effort to build a sustainable community but is not within the scope of the IRP					
If yes, predecessor			6, 11	6, 7, 11	7, 12	6, 12	11, 12
If yes, how will the technology improve the SDG?			Technology provides jobs for equality, economic wealth for those who can develop	Technology can provide opportunities to de-scale the inequalities through job creation	These technology help to prevent climate change and producing cleaner energy	Renewable technologies can help out by cleaning ocean water	Promoting better technology for energy generation to spare the earth resources and improve earth standards
If yes, how will the SDG improve?			Less inequalities with the genders in all communities	More jobs for the most affected workforce and labour to promote reducing inequalities	The SDG will improve through evident lower deterioration of the earth over a period of time.	More sea life below water and sustainable growth in the sea life	Earth resources will be stored and life on land can be sustainable
If yes, challenges			Inexperienced workforce, costly to train	Lack of workforce that would want to work	Lack of technology feasibility within SA	Unstable ocean waters and quantity of the problem	Sustainability of the production of technology and maintenance

Concluding remarks of Step 2

Step two discussed the various technologies available to the energy sector. This step discussed the linking of coal, nuclear, gas and renewable technologies. The case study provided information about the technologies in order to use the different technologies to strive towards the SDGs.

Depending on the path of step one, renewable technologies are far more diverse throughout the various SDGs, where other technologies illustrate other varieties of SDGs they could contribute towards.

In the next step, each technology is illustrated using a flow diagram (refer to Figures 8.2, 8.3, 8.4 and 8.5). Step three analyses these figures and compares the results with step 1 in order to find the most relevant technologies for the energy sector when linking both to SDGs.

8.2.4 Step 3

From the template, Figure 7.5 in section 7.3.4, the following figures can be developed based on the previous steps of the case study. These figures show which SDGs can be directly and indirectly improved.

The industry connection towards SDGs in step 1 is concluded in Figure 8.1. This figure represents the SDGs the energy sector currently strives for through the help of technology. This framework assumes that SDG 8, 9 and 17 forms part of the cornerstones and therefore is applicable to each industry. From the cornerstone SDGs, the direct SDGs were identified in Table 8.3 and the indirect SDGs in Table 8.4. This figure is compared to those from each technology in order to identify which technology is most relevant to the industry flow diagram.

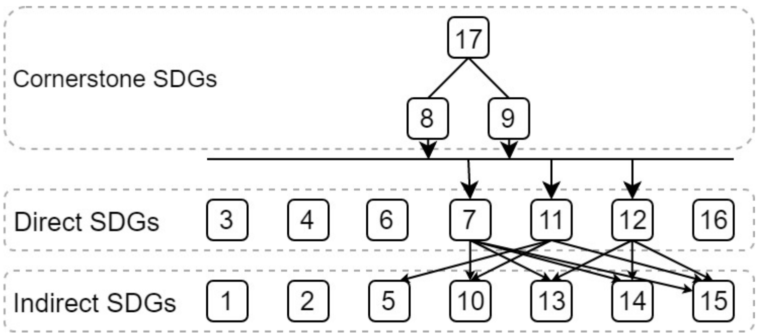

Figure 8.1: Industry desired impact on SDGs.

The conclusion from step 2 is evident in Figures 8.2, 8.3, 8.4 and 8.5 with these figures describing the linkages between the technology and SDGs. From the cornerstone SDGs, the direct SDGs were identified in Tables 8.7, 8.11, 8.15 and 8.19, and the indirect SDGs evident in Tables 8.8, 8.12, 8.16 and 8.20. This figure is compared to those from each technology in order to identify which technology is most relevant to the industry flow diagram.

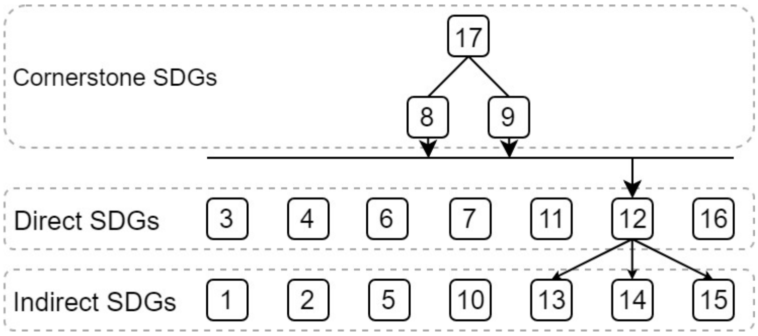

Figure 8.2: Outlook of coal technology impact on SDGs.

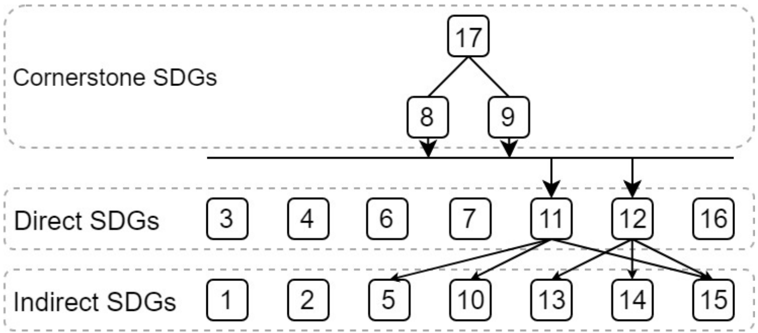

Figure 8.3: Outlook of nuclear technology impact on SDGs.

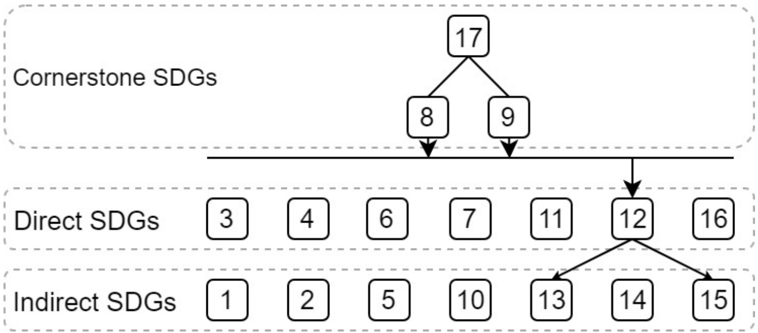

Figure 8.4: Outlook of gas technology impact on SDGs.

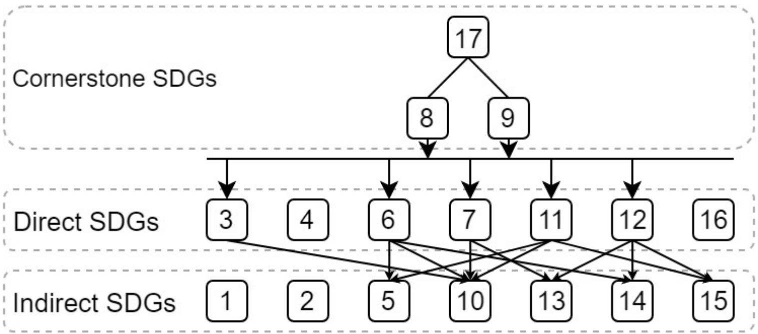

Figure 8.5: Outlook of renewable technology impact on SDGs.

8.2.5 The output

The framework output supports the IRP released by the energy sector of South Africa. It is evident that renewable technology is the most applicable technology (according to this framework) when aligning the technologies with SDGs and that of industry.

Coal and gas technologies, according to the pathways provided in this case study, are non-desirable for SD unless otherwise proven and/or the technology is improved. These pathways (refer to Figures 8.2and 8.4) are supported by the case study documents and evident in the case study that these technologies cannot be used for SD.

To conclude the output of this case study, it is evident that replacing technologies help industry move towards sustainability. Therefore, this framework could be used within any industry in need of replacing or incorporating technology in order to strive towards the SDGs and ultimately achieve sustainability.

The present case study provides insight into the practical use of the framework. This framework could be used in various situations and has the ability to work with various levels of input data, thereby producing detailed reports based on the quality of these input data. Features such as these enable the framework to be generic and user friendly.

The information gathered within the framework could guide an industry in terms of what to focus on, what challenges might be faced and lastly, which of the SDGs it may improve. The framework could also be further analysed, improved or adapted to align with the current state of the industry or technology.

8.3 Case study discussion

The energy industry case study provides valuable insights into how the framework can be used and the applicability thereof. The results of this case study confirm that the framework is applicable to the energy sector. Moreover, the results highlights that the framework can aid industries in providing strategic direction to improve their contribution towards sustainability and the SDGs through the use of technologies.

8.3.1 Design requirements

The framework has been designed in such a way that it can be applied to any industry. The case study provides sufficient practical use of the framework through applying the framework in the South African energy sector and multiple technologies.

This case study provides sufficient evidence for the first design requirement, namely the generic model. The case study showed that it is easy to apply within the industry. The framework does, however, entail some degree of complexity due to the number of industries and vast number of technologies that exist.

This framework provides an industry with a degree of connectivity between the chosen technologies and industry. The framework connects the entities through the means of SDGs. Moreover, it provides guidance (in terms of SDGs) in choosing a technology, recognises the sustainability factor and improves the sustainability of the industry (based on the results of the framework).

8.3.2 Strategic decision management

According to the comments of SMEs on the strategic decision management section (refer to section 7.4.3.2) and the case study, it is evident that there are numerous factors influencing the decision maker when deciding between technologies. It is clear from the SME interviews (section 7.4.3.2) that financial information regarding technologies and their implication on the decision maker is a factor of paramount importance in the decision-making process. However, this framework could provide guidance prior to choosing a certain technology based on financial credibility, with a slight difference having a major impact (whether positive or negative) on the SDGs.

8.3.3 Framework input, steps and output

The overall flow of the framework is applicable and practically feasible as evident from this case study. The framework provide feasible guidance for the decision maker when choosing between technologies when the decision is solely based on SDGs. The required steps set out by the framework are applicable to the relevant design requirements and the overall output of the framework is sufficient within the scope of this thesis.

The output, as previously stated, only provides information relevant to the SDGs and their contributions towards the SGDs. The framework's output could be used in conjunction with other frameworks, approaches and models to contribute towards a bigger decision-making structure.

This framework is applicable to the energy sector due to the fact that it connects the SDGs that it could be seen as a network. Literature has provided that the relation between energy and industrialisation have not yet been made. Meaning, the use of energy in economic infrastructure drives overall usage, while this correlates with some the SDGs. These weak linkages between the SDGs is evident throughout the energy sector, where a network could be generated between SDGs (Le Blanc, 2015).

8.4 Chapter 8: Conclusion

Chapter 8 explains the applicability of a case study and why it was executed. It further describes the case study documents that were used to complete the case study. The case study is presented in section 8.2, where after the chapter is concluded with a case study discussion.

Chapter 9

Conclusions and recommendations

This chapter presents a brief summary of the research, an account of the attainment of the research objectives and limitations of the study. Finally, the chapter concludes with recommendations for future work.

9.1 Research summary

This section presents a summary of the study according to each chapter. Each chapter and its key findings are discussed.

Chapter 1 provides an introduction to this study by first discussing the background of the study, and further explains the research aim and objectives. Chapter 1 also outlines the research limitations and concludes with a brief overview of the thesis.

Chapter 2 introduces the research methodology. Grounded Theory, applied to this work, is described and the Conceptual Framework Analysis as a method to achieve the research objectives set out in Chapter 1 is further discussed.

In **Chapter 3**, the role of technology towards Sustainable Development (SD) within the South African context was investigated. A systematic literature was conducted in order to identify the technologies currently used in South Africa to foster SD. Even though it is evident, that technology is used to foster SD in South Africa, some crucial limitations that restrict the use of technology to contribute towards SD are poverty, unemployment, an under-skilled workforce and lack of appropriate management. The systematic review outlined in Chapter 3 further revealed that Information and Communication Technologies (ICT) are being used in most sectors to pursue the connectivity of supply chain activities.

Currently there is a vast number of innovations towards technology to support SD. **Chapter 4** identifies the unused, new and emerging technologies to foster sustainable Socio-Technical (ST) transitions. This chapter identifies six different technology categories, and further identifies technologies within the categories, explains the opportunities and describes potential threats.

From Chapter 4, it is evident that there are various types of emerging technologies that could help reach SDGs. Lastly, Chapter 4 discusses some of the potential technologies that the South African environment could benefit from.

Chapter 5 discusses SD, SDGs and identifying South Africa's SDG areas for improvement. This chapter provided relevant information regarding the current SDGs set out by the United Nations (UN) which are stepping stones for success. These SDGs, with the help of the UN, provide platforms and frameworks for countries to improve the conditions within each country. Chapter 5 further reports on the current status of South Africa's SDGs performance and shows that a paucity of information is a major hurdle for the country. Chapter 5 concludes that through achieving one SDG, other SDGs can be achieved more easily. As such, implementing the right technologies could enhance the status of SD in South Africa.

Chapter 6 identified and discussed existing frameworks, approaches and models within the field of technology transition and technology adoption. Technology transition and adoption theories were discussed and the most suitable attributes were listed in Table 6.2. The chapter concluded with the design requirements of the proposed conceptual framework.

Chapter 7 introduces the developed framework. First, the relationship of the three entities (industry, technology and SDGs) are interconnected, followed by the linking of industries and technologies towards SDGs. An explanation on how industry and technology influence one another is provided. The framework, *Industry and technology alignment with SDGs framework*, were discussed in section 7.2 and explains how the framework works. This framework culminates towards the usage of the framework, as explained in section 7.3. The chapter concludes with the first part of the validation process, which include interviews with Subject Matter Experts (SMEs) within the field.

Chapter 8 discusses the applicability of the developed framework through a case study. This chapter described the objective of the case study and how it was executed. The presentation of the case study is found in section 8.2 and a case study discussion in section 8.3.

The final chapter, **Chapter 9**, concludes the study with a summary of the research conducted, research objectives and makes recommendations for future work.

9.2 Summary of research objective

The primary aim of this research study was to develop a framework to connect industries and technologies through means of SDGs. In order to achieve this, the present study set out to achieve four objectives. The conclusions of these objectives are discussed below:

9.2.1 Conclusions: Objective 1

Objective 1
Investigate the role of technology in SD, as well as the factors that enable and/or limit technology in contributing towards transitioning to sustainable systems. In addition, the role of technology in SD in South Africa is investigated. The focus will primarily be to: (a) Investigate what technologies are currently being employed in South Africa to support the aim of SD. Develop a clear understanding of the extent of use of technology in South Africa in the process of fostering SD; and (b) Gain an understanding of available or emerging technologies that could potentially have a significant impact in South Africa in terms of SD.

In order to address the first objective, systematic literature review was conducted. The systematic review provided relevant literature (refer to Chapter 3) from these studies, it was concluded that Information and Communication Technologies (ICT) is the most common technology being employed in South Africa to foster SD. In addition to this objective, the second sub-objective is achieved in Chapter 4, in which the emerging technologies is identified and discussed in relation to their impact on SD and SDGs within South Africa. Due to the vast number of emerging technologies, technology categories were identified and further discussed in Chapter 4.

9.2.2 Conclusions: Objective 2

Objective 2
Gain an understanding of how SD is fostered within South Africa and the current challenges faced in terms of moving towards sustainability. In addition, the study will investigate South Africa's current state on SDGs and areas of improvement through technological advancements.

Currently, South Africa fosters SD with the help of a number of platforms, frameworks and entities. Chapter 5 elaborates on the current strategies in place within South Africa to foster SD and more specifically, SDGs. The lack of data within South Africa remained a problem when reporting on the current status of SDGs and the progress South Africa has made.

The current challenges were further discussed in Chapter 5 to facilitate an understanding of why certain areas fail to improve and identifies focus areas for the South African environment. The current standing of South Africa in terms of SDGs was provided in section 5.2.1. From this, it is evident that South Africa has potential to improve/achieve SDGs.

9.2.3 Conclusions: Objective 3

Objective 3
Determine the applicability of the developed frameworks, approaches and models to the design requirements to guide decision makers in choosing technology(ies) implementation within an industry in order to improve and/or contribute toward SDGs. (a) Investigate how existing frameworks, approaches and models guide decision makers in choosing between technologies for SD and more specifically, SDGs. (b) Determine the applicability of the existing frameworks, approaches and models in relation to the design requirements in order to effectively support the process of implementing technology to contribute to and/or improve SDGs.

The existing frameworks, approaches and models were investigated to determine how they guide decision makers in choosing between technologies for SD and SDGs. Table 6.2 refers to a short summary of the attributes that were further considered when the conceptual framework was developed.

The applicability of the existing frameworks, approaches and models were discussed in Chapter 6, where it was found that there is no existing framework, approach or model that fits the desired design requirements asset out in section 6.1.

9.2.4 Conclusions: Objective 4

Objective 4
Develop and validate an framework that will guide the choice of technology(ies) for implementation within an industry to contribute to and/or improve SDGs. In addition, execute a case study to reveal the practical applicability of the conceptual framework. (a) To develop a conceptual framework that may support and guide decision makers within industries, in choosing technology(ies) for implementation that will contribute to and/or improve SDGs. (b) Validate the conceptual framework by engaging with Subject Matter Experts (SMEs) in the field. (c) Perform a case study to explore and discuss the practical application of the conceptual framework.

A conceptual framework was introduced in Chapter 7, with this chapter emphasising the necessity to link industry and technology through SDGs.

The framework was further discussed and explained, after which the framework was validated through interviews with SMEs. The semi-structured interviews generated qualitative data, which was then discussed and the necessary adaptations to the framework were made.

Thereafter, in Chapter 8, an application of the framework to the energy industry was performed to highlight the practicality of the framework. The case study provided a different outlook on the framework and presented an up-close, in-depth and detailed application of the framework.

9.3 Study limitations

Limitations that arose from the study are discussed in section 1.5. These limitations should be taken into consideration when interpreting the findings of this study.

The framework is applicable to all industries and technologies. There was, however, a limitation with regard to which industries the interview participants operates in. The validation process did not include feedback from an experts across a range of industries. Given the different positions of the SMEs within their respective industries, the data from each SME may not be representative of their respective industries.

The case study developed with the help of the framework was due to the sufficiency of the case study and the applicability to the relevant resources currently active within South Africa.

Due to the scope of this thesis, the developed framework does not include other factors (other than those identified in chapter 7) that may influence the decision maker in choosing between technologies. The developed framework contributes an additional factor to those that influence the decision-making process and needs to be further researched.

The next section provides recommendations for future studies. Some of these recommendations for future studies are derived from the limitations set out in the above section.

9.4 Future study recommendations

This section outlines the future research opportunities based on the findings of the present study. It is clear that ST transitions towards sustainability are complex in nature.

The developed framework enables an industry to connect with technology through the means of desired SDGs. Through this, it is evident that research is needed to establish the other factors that may influence the decision-maker. A network that consists of the various factors influencing the decision-maker, should be explored and developed. Further research should be conducted on this framework in order to add to evidence-based research.

Investigation towards technology pathways for SD transitions and implementation of such technologies in developing countries should be conducted. These technology pathways may provide more insight into the Multi-Level Perspective (MLP) and provide a more complete view of transition.

Within developing countries, numerous factors are evident within the system and restrict and/or govern transitions towards SD. Research in the field of platform technologies within developing countries should be undertaken. Developing countries may benefit from technologies such as platform technologies (which provide a platform for other applications and/or processes and/or technologies to be built on). Platform technologies can support SDGs and developing countries and excel the connectivity of the country as a whole.

South Africa, like most other countries, is transitioning towards a green economy. The link between transitioning towards green economy and SD should be explored. The research should include factors such as differences between transitions, aimed at achieving SDGs and sustainability of green economy. Strategies that involve a green economy should be established in order to strive towards SDGs and enable resilience within the environment to adapt to necessary changes.

9.5 Chapter 9: Conclusion

Developing countries like South Africa are full of potential. The linkage of industry and technology towards SDGs has the potential to help the current state South Africa and other developing countries are in. Technological innovation and development within developing countries has seen continuous improvements with regard to SDGs. As such, future investment in the linkages between industries and technologies towards SDGs is encouraged.

This thesis set out to develop a framework to link industry and technology through means of SDGs. There are a paucity of existing frameworks, approaches and models within this field. In light of this, a framework was developed. The framework was validated through SME interviews and a case study within the energy sector of South Africa in order to provide evidence for the practical use of the framework.

The present chapter concludes the research study and discusses recommendations for research. The author believes that this study and framework could provide both inspiration and technological direction to industries striving towards SD and SDGs.

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Appendix A

Validation workshop document

1. Proposed framework

The purpose of framework is to create a link between the industry and technology by connecting both, industry and technology, to the SDGs. This is then used to enable alignment between an industry and technology to work together in order to contribute towards the achievement of goals and promote SDGs. Figure 1 shows the connections that are needed in order to build framework.

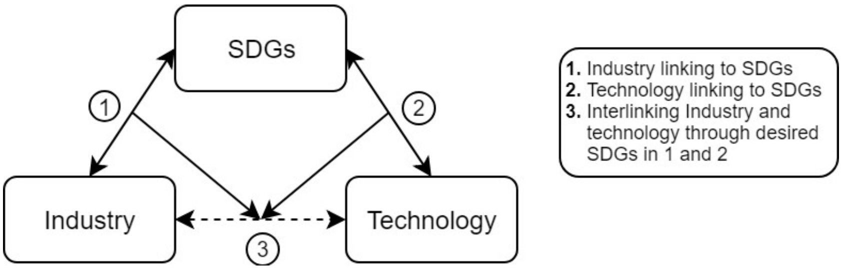

Figure 1: Entities within the framework.

1.1. The design requirements

In order to achieve the specific outcome with the framework, design requirements have been developed and subsequently met in order to achieve the desired outcome of the proposed framework. The design requirements consist of the follow:

1. ***Generic model*** – the ability to be applicable to each industry adopting technology;
2. ***User friendly*** – easy to use framework when choosing between technologies when striving towards sustainability;
3. ***Identify industry contribution towards SDGs*** – Identifying which SDGs the industry aims to improve and/or contribute towards;
4. ***Connects entities (Industry, Technologies and SDGs)*** – while considering the entities from an industry perspective, the framework should facilitate aligning the entities with the desired (and/or selected) SDGs (based on the identification of relevant SDGs in (3));
5. ***Guidance for choosing technologies*** – by applying technology within an industry, the industry has to be clear on the end goals and which technologies support the contribution of the industry towards specific SDGs; and
6. ***Recognise and improve sustainability*** – with sustainable development as a key business component, considering the SDGs and being sustainable within an industry is key.

1.2. The Industry and technology alignment with SDGs framework

Figure 2 illustrates the proposed framework which is later used as a process (Refer to section 1.3). Figure 2 shows how all the SDGs can be focused upon structuring infrastructure around the concurring SDGs.

The different circles in Figure 2 represents different focus levels where the inner circle is the key focal point. The inner circle, circle 1, consist of goal 17. This is at the core of this framework and is solely based on the concept of partnerships. Partnerships for goals and partnerships on its own holds considerable value when aiming to connect and align the supply chain or industries, making it easier for the industries to cooperate.

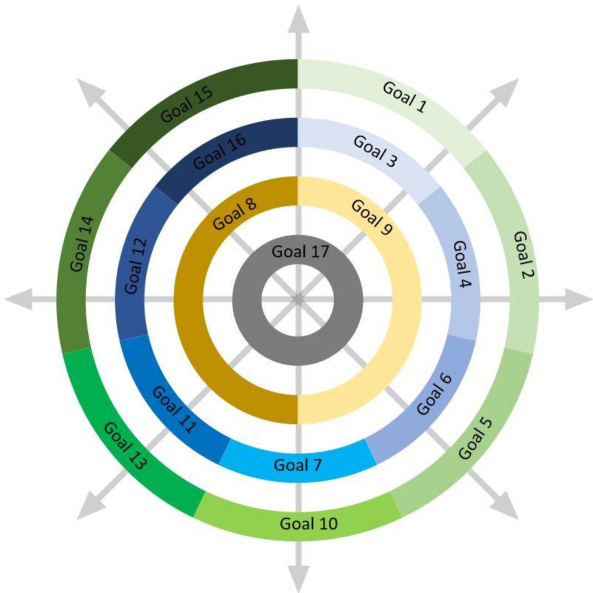

Figure 2: Creating and showing how all SDGs can be focused upon.

Circle 2 represents goal 8 and 9. The objective of goal 8 is to support the industry to ensures the stability of the working environment and economic growth. Whereas the objective of goal 9 is to ensure that industries keep striving for innovative ideas within their respective industry and to ensure the maintaining of the infrastructure within the entire industry.

Through the help of the inner two circles, the planning, infrastructure and implementation to support the outer circles improve. These two inner circles represent the cornerstone part of framework and is essential for any industry to foster these goals.

Circle 3 consist all SDGs that can directly be influenced by actions and have an effect on other SDGs. These SDGs (SDG 3, 4, 6, 7, 11, 12 and 16) that forms part of the process towards sustainable development and entails improving the living conditions of citizens in a country and protecting the environment. By acting, industries can easily identify which SDGs in this circle are the ones on which they have an impact, and that they can (ideally) improve and/or contribute towards. The key idea is that by improving and / or contributing towards the SDGs represented in this circle in turn enables the industries to affect indirectly circle 4.

The outer circle, circle 4, represents the SDGs that can be improved and eventually accomplished when SDGs in the inner circles are improved and/or has been fully achieved. Circle 4 represents the SDGs that can be focused on when the other SDGs gains momentum and shown improvements. The SDGs presented in circle 4, seen in Figure 2, can be improved through other SDG improvements. For example, by improving the education system and creating opportunities, more people could potentially gain access to working opportunities making it possible to support their families in need and end up improving SDG 1. By focusing on circle 1 and 2 within Figure 2, it is possible that circle 3 and 4 can improve without specifically focusing on specific goals, highlighting the interrelatedness of the SDGs...

From inside to outside in Figure 2, the circles can be seen as building blocks to achieve all SDGs in coherent, and arguably more efficient and effective way. The next section describes the framework process, which is divided into three different steps with the input described before step 1 and the output at the end of step 3. In the following sections the framework is explained in further detail.

1.3. The Industry and technology alignment with SDGs framework usage

The proposed framework (refer to Figure 2) is translated into a process (seen in Figure 3). The usage of this framework requires input (refer to section 1.3.1) and consists of 3 steps that is explained in section 1.3.2 – 1.3.4. Step 1 and 2 is independent of one another, where step 3 continue on the outcomes of step 1 and 2. The outcome of the framework is derived from step 3 where the industry and technology are aligned with their mutual desired SDGs.

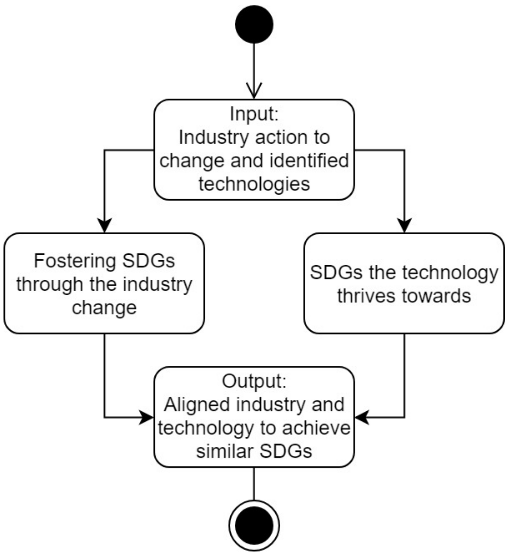

Figure 3: The Industry and technology alignment with SDGs process.

1.3.1. The input

In order for any industry to use the framework, it is necessary that the industry has the inputs required to start with the framework. The following input is required from the industry:

- Identified industry type;
- Identified activity within a division of the industry wishing to change; and
- Technologies aiming to implement.

The framework can be used by any industry. Thus, the user of the framework has to identify the necessary industry it will report on. The second input required, an identified activity wishing to change within a certain division in the industry. Lastly, the technologies identified by the industry which they aim to implement for future use in that specific activity in the industry. The industry activity towards being more sustainable includes the replacement or implementation of technology within the industry. Thus, making this framework applicable when industries want to replace or incorporate technology into the industry to strive towards the SDGs and ultimately achieving sustainability.

The framework can be used in various situations. The framework has the ability to function with various level of input data, which produces detail reports based on the quality of the input. These features aim make this framework generic and user friendly. The information put into the framework, can guide the industry on what to focus on, what challenges it might face and lastly what SDGs it can improve. The framework can also the be further analysed, improved or adapted to align with the current state of the industry or technology.

1.3.2. Step 1: Linking of the industry to SDGs

Within this framework, the first step would be to set out the SDGs that is aimed to be improved or contributed towards through the action of the industry. By applying Figure 3 to circle 1, 2, 3 and 4 of Figure 2 and providing a stepwise process, Table A, B, C and D have been developed respectively. Starting with Table A and B, the industry has to identify the "actors within the industry". This question is followed by "actions between actors to affect SDG" and lastly the "challenges" is identified.

Table A: Circle 1 for Industry

Cornerstone SDGs	Goal 17: Partnerships to achieve goal
Identifying actors within the industry	
Actions between actors to affect the SDG	
Challenges	

Table B: Circle 2 for Industry

Cornerstone SDGs	Goal 8: Decent work and economic growth	Goal 9: Industry, innovation and infrastructure
Action of industry to improve SDG		
How will this action affect the SDG		
Challenges		

After Table A and B have been completed, the industry then has to identify what SDGs in circle 3 it will aim to improve or contributed towards. In Table C (referring to circle 3), the industry has to identify wherever the industry can or cannot contribute towards and/or improve the SDGs. This is followed by providing information on "how the industry can improve the SDG" or provide a reason "why not". Table C further investigates "how the SDG will improve" and what are the possible "challenges" it might face when trying to improve or contribute towards the SDG.

Table C: Circle 3 for Industry

Direct SDGs	Goal 3: Good health and well-being	Goal 4: Quality education	Goal 6: Clean water and sanitation	Goal 7: Affordable and clean energy	Goal 11: Sustainable cities and communities	Goal 12: Responsible consumption and production	Goal 16: Peace, justice and strong institutions
Applicability (Yes/No)							
If No, why not?							
If yes, how will the industry improve the SDG							
If yes, how will the SDG improve?							
If yes, challenges							

Table D represents the fourth and last circle. These SDGs are indirectly affected through the previous circles. Once again, the industry has to identify wherever the industry can or cannot improve and/or contributed towards the SDGs. If the specific SDG can be improved, the industry has to provide the predecessor(s) (SDGs in circle 3 that will contribute towards SDG in circle 4) in order to create a flow diagram (refer to Figure 4 in section 2.3.4). The last number of questions include "how the industry can improve the SDG" or provide a reason "why not". Table D concludes by investigating how the SDGs will improve "and what are the possible challenges" it might face when trying to improve or contribute towards the SDG.

Table D: Circle 4 for Industry

Indirect SDGs	Goal 1: No Poverty	Goal 2: Zero hunger	Goal 5: Gender equality	Goal 10: Reduced inequality	Goal 13: Climate action	Goal 14: Life below zero	Goal 15: Life on land
Applicability (Yes/No)							
If no, why not?							
If yes, predecessor							
If yes, how will the industry improve the SDG							
If yes, how will the SDG improve?							
If yes, challenges							

1.3.3. Step 2: Linking of technology to SDGs

This step includes the technologies identified in the input stage. Step 2 has to be repeated for each technology identified at the input data. s. This step will provide the industry with information on how the technologies foster SDGs and subsequently the step can assist in identifying which technology/ies are best suited for the action set out to change within the industry (as discussed in the input data). This step is similar to step 1, which makes use of Figure 2 to produce four separate tables. However, it reflects on the technology and how the technology can and will be used to foster SDGs, while step 1 reflects the industry alignment with SDGs.

This second step is to map out the SDGs that is aimed to improve through the action of the technology. Altering the questions in Table A, B, C and D to fit the technology environment, Table E, F, G and H have been developed, which represents circle 1, 2, 3, and 4 respectively. Starting at Table E and F, the industry has to identify "the actors within the technology environment". This question is followed by "how will this technology affect the SDG" and lastly the "challenges" is identified.

Table E: Circle 1 for Technology

Cornerstone SDGs	Goal 17: Partnerships to achieve goal
Identifying actors within the technology environment	
Actions between the actors to affect the SDG	
Challenges	

Table F: Circle 2 for Technology

Cornerstone SDGs	Goal 8: Decent work and economic growth	Goal 9: Industry, innovation and infrastructure
Action of technology to improve SDG		
How will this technology affect the SDG		
Challenges		

After Table E and F have been completed, the possible SDGs that can be improved by the technology has to be identified. As described, these SDGs are directly reachable and these will feed off to the last circle. In Table G (refer to circle 3), the applicability has to be answered whether or not the technology can affect the SDG. This is followed by providing "how the technology can improve the SDG" or provide a reason "why not". Table G further probes "how the SDG will improve" when applying the technology and what are the possible "challenges" it might face when trying to improve or contribute towards the SDG.

Table G: Circle 3 for Technology

Direct SDGs	Goal 3: Good health and well-being	Goal 4: Quality education	Goal 6: Clean water and sanitation	Goal 7: Affordable and clean energy	Goal 11: Sustainable cities and communities	Goal 12: Responsible consumption and production	Goal 16: Peace, justice and strong institutions
Applicability (Yes/No)							
If no, why not?							
If yes, how will the technology improve the SDG							
If yes, how will the SDG improve?							
If yes, challenges?							

Table H represents the fourth and last circle, which contains the indirect SDGs. This SDGs are indirectly affected from the inner circles and can rely on multiple SDGs from circle 3 in Figure 2. If the SDG (in circle 4) can be improved, a predecessor(s) is applicable and must be reflected in Table H. These predecessor(s) are also required in step 3 of the framework in order to create a flow diagram (refer to Figure 4 in section 1.3.4). The last couple of questions includes "how the technology can improve the SDG" or provide a reason "why not". Table H concludes by asks "how the SDG will improve" when applying the technology and what are the possible "challenges" it might face when trying to improve or contribute towards the SDG.

Table H: Circle 4 for Technology

Indirect SDGs	Goal 1: No Poverty	Goal 2: Zero hunger	Goal 5: Gender equality	Goal 10: Reduced inequality	Goal 13: Climate action	Goal 14: Life below zero	Goal 15: Life on land
Applicability (Yes/No)							
If no, why not?							
If yes, predecessor?							
If yes, how will the technology improve the SDG							
If yes, how will the SDG improve?							
If yes, challenges?							

1.3.4. Step 3: Linking industry to technology through the outcomes of previous steps

Step 3 is the final step which concludes the outcomes of step 1 and 2 by creating a flow diagram (refer to Figure 4). The industry flow diagram described the SDGs desired to improve. Thus, creating a flow diagram for each technology, one could see if there is a specific technology for these industries and SDG driven actions or are there multiple technologies to choose from. These flow diagrams can then be used as evidence when proposing a new change of technology or action within the industry and describes the benefits of the action and change of technology towards the SDGs.

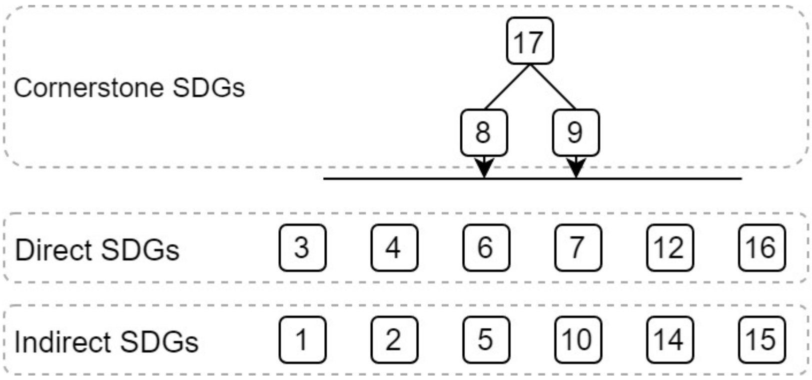

Figure 4: SDGs flow diagram

1.3.5. The output

The final outcome of the framework enables any industry to develop a statement which states the different identified technologies and which technologies support the industry goals. When changing within industry happens, it is necessary to build evidence to show why to change and the benefits (not only for the industry, but the country) to these changes. The outcome can be created as a full report or as a figure explanation on which technologies fits the industry's goals.

Appendix B

Validation Questionnaire and feedback

This Appendix contains the Questionnaire sent to each Subject Matter Expert (SME) for their feedback after the interview, where the framework was explained. This Appendix start with the template Questionnaire, which is then followed by the feedback from the SME's.

Table B.1 introduce the SME's and provide the occupation and affiliation of each SME. Their selection was based upon their relevance towards the implementation of technology for sustainability and research fields such as SD, technologies and knowledge of various industries. The SMEs embodied different roles within the technology/sustainability field including the research sector.

Table B.1: Professional interviewees

Validator	**Occupation and affiliation**
SME 1	Green technology manager at a non-profit organisation
SME 2	Energy Programme manager at a non-profit organisation
SME 3	Lecturer and researcher in the field at a university
SME 4	Project officer and Geoscientist at a non-profit organisation
SME 5	Associate professor in the field at a university

The feedback in this section start at SME 1 and ends at SME 4. SME 5 did not complete the questionnaire, however did gave valuable input towards the framework and how it is introduce. Upon completion of the interview process, the recordings of the interviews were deductively analysed towards identifying prominent opinions, shortcomings and useful recommendations for the improvement of the framework.

Due to the lack of completeness of some SME's questionnaire, the researcher did receive feedback via a telephonic conversation. SME 1 did responded on the question “Is the framework connecting the entities applicable and sufficient?” is “Agree”. SME 2 provided feedback in a telephonic conversation on “To what extent can this framework relate to the current number of industries?” with feedback of “Agree” and “How much of a difference can the output has within the decision-making process?” with feedback of “Unsure”.

Questionnaire:

Industry and technology alignment with SDGs framework

Document prepared by Joubert Spies

Contact information: 082 626 2701 or jsjoubertspies7@gmail.com

	Validation questions	Strongly Disagree	Disagree	Unsure	Agree	Strongly Agree	Comments
Design requirements	**Generic model**						
	To what extent can this framework relate to the current number of industries? Provide industry(ies) if possible when not applicable.						
	User friendly						
	Is the framework sufficiently introduced and explained?						
	Does the framework flow accordingly?						
	To what extent is the framework ease of use by the user?						
	Industry identifying contribution towards SDGs						
	During the use of the framework, is the evaluation of industry towards SDGs possible?						
	Is the outcome of the industry contributions towards SDGs realistic and reachable?						
	Connect entities (Industry, technologies and SDGs)						
	To what extent is the connection between entities realistic and feasible?						
	Is the framework connecting the entities applicable and sufficient?						
	Guidance for choosing technologies						
	To what extent does the framework provide realistic and feasible guidance?						
	Is the guidance towards technology effective and sufficient?						
	Recognise and improve sustainability						
	Does this framework recognise sustainability realistically?						
	To what extent does the framework improve the sustainability?						

Strategic decision management	*To what extent can this framework influence the decision maker?*							
	How much of a difference can the output has within the decision-making process?							
	Did the researcher provide a …	*… plausible tool that influence the decision maker?*						
		… framework that is logical reasoning?						
		… framework that is compelling enough to affect the decision maker?						
Framework design	*Is the layout of circle 1 and 2 applicable, practically feasible and logical reasoning?*							
	Circle 3, to what extent is this circle applicable, practically feasible and logical reasoning?							
	Circle 4, to what extent is this circle applicable, practically feasible and logical reasoning?							
	Is the design of the framework sufficient, applicable and feasible?							
Input	*To what extent is the industry action applicable and feasible?*							
	Is it possible to identify technologies as an input?							
	Within practise, is the input practically achievable?							
Process	**Step 1**	***TABLE A*** *- To what extent is this table applicable, practically feasible and logical reasoning?*						
		TABLE B *- To what extent is this table applicable, practically feasible and logical reasoning?*						
		TABLE C *- To what extent is this table applicable, practically feasible and logical reasoning?*						
		TABLE D *- To what extent is this table applicable, practically feasible and logical reasoning?*						
		Overall flow of tables, information regarding the tables and practicality of the tables? (Please provide comments)						

	Step 2	***TABLE E*** *- To what extent is this table applicable, practically feasible and logical reasoning?*						
		TABLE F *- To what extent is this table applicable, practically feasible and logical reasoning?*						
		TABLE G *- To what extent is this table applicable, practically feasible and logical reasoning?*						
		TABLE H *- To what extent is this table applicable, practically feasible and logical reasoning?*						
		Overall flow of tables, information regarding the tables and practicality of the tables? (Please provide comments)						
	Step 3	*Is the flow diagram (Figure 4) appropriate for practical use?*						
		Does step 3 provide the decision maker with suitable information?						
		To what extent does step 3 provide sufficient and effective guidance?						
Output	*To what extent are the output valid?*							
	How worthy are the output of the framework?							
	Does the framework provide appropriate, suitable and sufficient evidence?							
Overall review	*To what extent do you agree that this framework does what it says it does?*							
	How strongly do you agree that this framework is of high quality?							
	From your experience with the framework, what are the pivotal aspects within the process?							
	Lastly, is there any difficulty within the guidance and usage of the framework (if any)?							

Questionnaire:

Industry and technology alignment with SDGs framework

Document prepared by Joubert Spies

Contact information: 082 626 2701 or jsjoubertspies7@gmail.com

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	Validation questions		Strongly Disagree	Disagree	Unsure	Agree	Strongly Agree	Comments
Design requirements	**Generic model**							
	To what extent can this framework relate to the current number of industries? Provide industry(ies) if possible when not applicable.					X		Relies on partnerships being successful to really work.
	User friendly							
	Is the framework sufficiently introduced and explained?				X			I had to go through it twice before I understood it.
	Does the framework flow accordingly?					X		
	To what extent is the framework ease of use by the user?				X			Very qualitative. Decision makers like data.
	Industry identifying contribution towards SDGs							
	During the use of the framework, is the evaluation of industry towards SDGs possible?					X		
	Is the outcome of the industry contributions towards SDGs realistic and reachable?							Reachable is dependent on budget and interventions.
	Connect entities (Industry, technologies and SDGs)							
	To what extent is the connection between entities realistic and feasible?				X			How to reference qualitative data between different sources.
	Is the framework connecting the entities applicable and sufficient?				X			Decision makers also care about budget
	Guidance for choosing technologies							
	To what extent does the framework provide realistic and feasible guidance?					X		
	Is the guidance towards technology effective and sufficient?				X			doesn't take into account budget.
	Recognise and improve sustainability							
	Does this framework recognise sustainability realistically?						X	
	To what extent does the framework improve the sustainability?						X	
Strategic decision management	To what extent can this framework influence the decision maker?				X			Strongly agree if SDG is only decision making criteria
	How much of a difference can the output has within the decision-making process?				X			
	Did the researcher provide a ...	... plausible tool that influence the decision maker?				X		
		... framework that is logical reasoning?				X		
		... framework that is compelling enough to affect the decision maker?			X			

Framework design		Is the layout of circle 1 and 2 applicable, practically feasible and logical reasoning?				X		
		Circle 3, to what extent is this circle applicable, practically feasible and logical reasoning?				X		
		Circle 4, to what extent is this circle applicable, practically feasible and logical reasoning?				X		
		Is the design of the framework sufficient, applicable and feasible?			X			
Input		To what extent is the industry action applicable and feasible?				X		
		Is it possible to identify technologies as an input?					X	if they are broad.
		Within practise, is the input practically achievable?				X		
Process	Step 1	**TABLE A** - To what extent is this table applicable, practically feasible and logical reasoning?				X		State qualitative data only? What level of detail is needed.
		TABLE B - To what extent is this table applicable, practically feasible and logical reasoning?				X		Add what needs to be done to overcome challenges.
		TABLE C - To what extent is this table applicable, practically feasible and logical reasoning?				X		Could you add quantitative data?
		TABLE D - To what extent is this table applicable, practically feasible and logical reasoning?				X		What if the centre of the circle changed?
		Overall flow of tables, information regarding the tables and practicality of the tables? (Please provide comments)				X		
	Step 2	**TABLE E** - To what extent is this table applicable, practically feasible and logical reasoning?				X		Make sure to explain that it compares how one is better.
		TABLE F - To what extent is this table applicable, practically feasible and logical reasoning?				X		Surely they all have impact from manufacturing?
		TABLE G - To what extent is this table applicable, practically feasible and logical reasoning?				X		Should affect all SDGs – some positive, some negative & some more than others.
		TABLE H - To what extent is this table applicable, practically feasible and logical reasoning?				X		
		Overall flow of tables, information regarding the tables and practicality of the tables? (Please provide comments)				X		
	Step 3	Is the flow diagram (Figure 4) appropriate for practical use?			X			complicated to understand. What
		Does step 3 provide the decision maker with suitable information?			X			Without how much it costs to implement can I make a decision?
		To what extent does step 3 provide sufficient and effective guidance?			X			

Output	*To what extent are the output valid?*			X			
	How worthy are the output of the framework?				X		
	Does the framework provide appropriate, suitable and sufficient evidence?				X		would be better @ quantitative level.
Overall review	*To what extent do you agree that this framework does what it says it does?*					X	
	How strongly do you agree that this framework is of high quality?				X		
	From your experience with the framework, what are the pivotal aspects within the process?	That the partnerships are working. Goal 17: taken from developing world. is this the right centre for us?					
	Lastly, is there any difficulty within the guidance and usage of the framework (if any)?	i found it complex the first time second time was better.					

Questionnaire:

Industry and technology alignment with SDGs framework

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Contact information: 082 626 2701 or jsjoubertspies7@gmail.com

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	Validation questions		Strongly Disagree	Disagree	Unsure	Agree	Strongly Agree	Comments
Design requirements	**Generic model**							
	To what extent can this framework relate to the current number of industries? Provide industry(ies) if possible when not applicable.							
	User friendly							
	Is the framework sufficiently introduced and explained?					X		Need up front Clear Gap being addressed "why"
	Does the framework flow accordingly?					X		
	To what extent is the framework ease of use by the user?				X			No practical model
	Industry identifying contribution towards SDGs							
	During the use of the framework, is the evaluation of industry towards SDGs possible?					X		
	Is the outcome of the industry contributions towards SDGs realistic and reachable?					X		
	Connect entities (Industry, technologies and SDGs)							
	To what extent is the connection between entities realistic and feasible?					X		
	Is the framework connecting the entities applicable and sufficient?					X		
	Guidance for choosing technologies							
	To what extent does the framework provide realistic and feasible guidance?				X			
	Is the guidance towards technology effective and sufficient?					X		
	Recognise and improve sustainability							
	Does this framework recognise sustainability realistically?					X		
	To what extent does the framework improve the sustainability?					X		
Strategic decision management	*To what extent can this framework influence the decision maker?*					X		Use model to select impact Tech
	How much of a difference can the output has within the decision-making process?							
	Did the researcher provide a ...	*... plausible tool that influence the decision maker?*			X			Good model Concept but Can't be Used
		... framework that is logical reasoning?				X		
		... framework that is compelling enough to affect the decision maker?				X		

Framework design		Is the layout of circle 1 and 2 applicable, practically feasible and logical reasoning?				X		
		Circle 3, to what extent is this circle applicable, practically feasible and logical reasoning?				X		
		Circle 4, to what extent is this circle applicable, practically feasible and logical reasoning?				X		
		Is the design of the framework sufficient, applicable and feasible?				X		
Input		To what extent is the industry action applicable and feasible?				X		
		Is it possible to identify technologies as an input?				X		
		Within practise, is the input practically achievable?				X		
Process	Step 1	**TABLE A** - To what extent is this table applicable, practically feasible and logical reasoning?				X		
		TABLE B - To what extent is this table applicable, practically feasible and logical reasoning?				X		
		TABLE C - To what extent is this table applicable, practically feasible and logical reasoning?				X		
		TABLE D - To what extent is this table applicable, practically feasible and logical reasoning?				X		
		Overall flow of tables, information regarding the tables and practicality of the tables? (Please provide comments)				X		
	Step 2	**TABLE E** - To what extent is this table applicable, practically feasible and logical reasoning?				X		
		TABLE F - To what extent is this table applicable, practically feasible and logical reasoning?				X		
		TABLE G - To what extent is this table applicable, practically feasible and logical reasoning?				X		
		TABLE H - To what extent is this table applicable, practically feasible and logical reasoning?				X		
		Overall flow of tables, information regarding the tables and practicality of the tables? (Please provide comments)				X		
	Step 3	Is the flow diagram (Figure 4) appropriate for practical use?				X		
		Does step 3 provide the decision maker with suitable information?				X		
		To what extent does step 3 provide sufficient and effective guidance?				X		

Output	*To what extent are the output valid?*				X		
	How worthy are the output of the framework?				X		
	Does the framework provide appropriate, suitable and sufficient evidence?				X		
Overall review	*To what extent do you agree that this framework does what it says it does?*			X			Need a bit of additional Working
	How strongly do you agree that this framework is of high quality?				X		
	From your experience with the framework, what are the pivotal aspects within the process?						
	Lastly, is there any difficulty within the guidance and usage of the framework (if any)?						

Questionnaire:

Industry and technology alignment with SDGs framework

Document prepared by Joubert Spies

Contact information: 082 626 2701 or jsjoubertspies7@gmail.com

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	Validation questions	Strongly Disagree	Disagree	Unsure	Agree	Strongly Agree	Comments
Design requirements	**Generic model**						
	How strongly do you agree that the framework is applicable to all industries? Provide industry(ies) if possible when not applicable.		x				Various industries would directly impact the "Indirect SDGs" e.g. social enterprise focussing on reducing poverty / addressing hunger and might through CSI influence any of the goals.
	User friendly						
	Is the framework sufficiently introduced and explained?				x		
	Do you agree that the framework flow accordingly?				x		
	The framework is user friendly and easy to use.			x			
	Industry identifying contribution towards SDGs						
	Do you agree that during the usage of the framework, the evaluation of industry towards SDGs is possible?			X			
	The framework identification of industry contributions towards SDGs are realistic and reachable?			X			
	Connect entities (Industry, technologies and SDGs)						
	The framework connects the industry, technology and SDGs in a feasible way				X		
	Does the framework connect the entities in a applicable manner?				X		
	Guidance for choosing technologies						
	Does the framework provide realistic and feasible guidance?			X			
	Is the guidance of the framework towards technology effective and sufficient?		X				Focusses on one very specific aspect
	Recognise and improve sustainability						
	Does this framework recognise sustainability realistically?			X			
	Does the framework improve the sustainability?				X		
Strategic decision management	*Can this framework influence the decision maker?*			X			
	The framework output has major impacts within the decision-making process?			X			
	Did the researcher provide a … … plausible tool that influence the decision maker?				X		
	… framework that is logic reasoning?				X		
	… framework that is compelling enough to affect the decision maker?				X		

Framework design		*Is the layout of circle 1 and 2 applicable?*					X		
		Is the layout of circle 1 and 2 practically feasible?					X		
		Is the layout of circle 1 and 2 logic reasoning?					X		
		Is circle 3 within the framework	*Applicable to industries*				X		
			Practically feasible				X		
			Logic reasoning			X			
		Is circle 4 within the framework	*Applicable to industries*				X		
			Practically feasible				X		
			Logic reasoning			X			
		Is the design of the framework sufficient?				X			
		Is the design of the framework applicable?					X		
		Is the design of the framework feasible?					X		
Input		*To what extent is the industry action applicable and feasible?*					X		
		Is it possible to identify technologies as an input?					X		
		Within practise, is the input practically achievable?				X			
Process	**Step 1**	***Is Table A in the framework...***	*Applicable?*				X		
			Practically feasible?				X		
			Logic reasoning?			X			
		Is Table B in the framework...	*Applicable?*				X		
			Practically feasible?				X		
			Logic reasoning?			X			
		Is Table C in the framework...	*Applicable?*				X		
			Practically feasible?				X		
			Logic reasoning?				X		
		Is Table D in the framework...	*Applicable?*				X		
			Practically feasible?				X		
			Logic reasoning?			X			
		This step has sufficient overall flow of tables and information (Please provide comments)				X			See comments attached.
	Step 2	***Is Table E in the framework...***	*Applicable?*				X		
			Practically feasible?				X		
			Logic reasoning?				X		

		Is Table F in the framework...	*Applicable?*				X		
			Practically feasible?				X		
			Logic reasoning?			X			
		Is Table G in the framework...	*Applicable?*				X		
			Practically feasible?				X		
			Logic reasoning?			X			
		Is Table H in the framework...	*Applicable?*				X		
			Practically feasible?				X		
			Logic reasoning?			X			
		This step has sufficient overall flow of tables and information (Please provide comments)					X		See comments attached
	Step 3	*The flow diagram (Figure 4) is appropriate for practical use?*					X		
		This step provides the decision maker with suitable information					X		
		Step 3 provide sufficient guidance					X		
Output	*To what extent are the output valid?*						X		
	How worthy are the output of the framework?					X			
	Does the framework provide appropriate, suitable and sufficient evidence?						X		
Overall review	*To what extent do you agree that this framework does what it says it does?*						X		
	How strongly do you agree that this framework is of high quality?					X			
	From your experience with the framework, what are the pivotal aspects within the process?			See note 1 below					
	Lastly, is there any difficulty within the guidance and usage of the framework (if any)?			See note 2 below					

1) It provides a good way of thinking through how the SDGs are affected or can be linked to a particular industry or technology. However, I am sceptical regarding how much a decision-maker will be swayed when choosing between different projects based solely on the framework. It seems more useful as a value add to support the other fundamentals of a project.

2) I would recommend a thorough language editing of the framework document. It seems the language use has some issues which confound the intended meaning at times.